

AD-A084 250

LOCKHEED MISSILES AND SPACE INC SUNNYVALE CA ADVANCE--ETC F/G 9/1
HIGH CONTRAST CRT FACEPLATE.(U)
APR 80 T 6 MAPLE

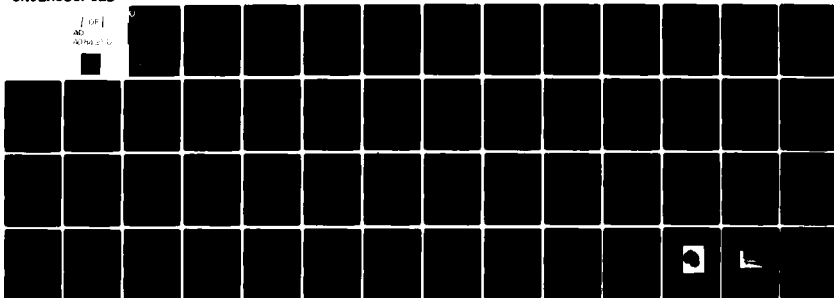
DAAK20-79-C-0282

UNCLASSIFIED

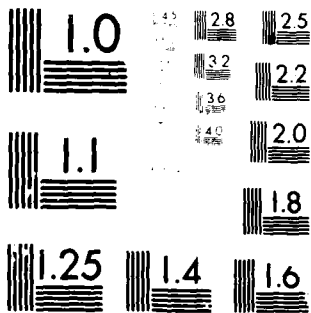
DELET -TR-79-0282-1

NL

1 OF 1
AD
2010010



END
DATE
FILMED
6-80
DTIC



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A



RESEARCH AND DEVELOPMENT TECHNICAL REPORT
CORADCOM-

DELET-TR-79-0282-1

HIGH CONTRAST CRT FACEPLATE

T. G. Maple
Advanced Systems Division
Lockheed Missiles & Space Co., Inc.
1111 Lockheed Way
Sunnyvale, California 94086

April, 1980 First Interim Report for Period 19 September 1979 - 18 January 1980

DISTRIBUTION STATEMENT

Approved for public release, distribution unlimited

Prepared for:

ELECTRONICS TECHNOLOGY AND DEVICES LABORATORY

RECEIVED
MAY 16 1980
A

CORADCOM

US ARMY COMMUNICATIONS RESEARCH & DEVELOPMENT COMMAND
FORT MONMOUTH, NEW JERSEY 07703

80 5 14 005

ADA084250

NOTICES

Disclaimers

The citation of trade names and names of manufacturers in this report is not to be construed as official Government indorsement or approval of commercial products or services referenced herein.

Disposition

Destroy this report when it is no longer needed. Do not return it to the originator.

HISA-FM-633-78

(Unclassified)

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER DELET-TR-79-0282-1	2. GOVT ACCESSION NO. AD-A084250	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle)		5. TYPE OF REPORT & PERIOD COVERED Interim Technical Report, 19 September - 18 Jan. 1980
		6. PERFORMING ORG. REPORT NUMBER LMSCD766118
7. AUTHOR(s) T. G. Maple		8. CONTRACT OR GRANT NUMBER(s) DAAK 20-79-C-0282
9. PERFORMING ORGANIZATION NAME AND ADDRESS Advanced Systems Division LOCKHEED MISSILES & SPACE CO., INC. 1111 Lockheed Way Sunnyvale, Ca 94086		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 1162703AH9403-01
11. CONTROLLING OFFICE NAME AND ADDRESS U.S. Army Electronics Research and Development Command Attn: DELET-BD Fort Monmouth, N.J. 07703		12. REPORT DATE April, 1980
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		13. NUMBER OF PAGES 49
		15. SECURITY CLASS (of this report) UNCLASSIFIED
15a. DECLASSIFICATION/DOWNGRADING SCHEDULE		
16. DISTRIBUTION STATEMENT (of this Report) Approved for public release; Distribution unlimited		
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)		
18. SUPPLEMENTARY NOTES		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) 3-inch CRT High Contrast Displays Two-Color CRT Thin Film Phosphor Color Penetration Tube		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) The objective of this program is the development of a high contrast, two color CRT faceplate employing evaporated thin film phosphors and nonreflective backing, utilizing 1710 glass and also sapphire substrates. Faceplates fabricated on type 1710 glass utilizing 1710 glass and also sapphire as substrates are comparable to those previously fabricated on 1720 glass. Chromatographic analysis indicates presence of a trace of elemental sulfur which may be the cause of reported cathode poisoning. The sulfur can be eliminated by a vacuum bake.		

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 68 IS OBSOLETE

(Unclassified)

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

(6)

HIGH CONTRAST CRT FACEPLATE
INTERIM TECHNICAL REPORT

11) Apr 84

19 SEPTEMBER 1979 THROUGH 18 JANUARY 1980

(17) 03/

Contract No. ⁽¹⁵⁾ DAAK 29-79-C-0282

(16) 1L1 62705AH94

(18) DELET

(19) TP-79-0323-2

Prepared by:

(10) T. G. Maple

(9)

Interim report 19 Sep 79-17
no. 2, Jan. 79

(12) 55/

A

For

U.S. Army Electronics Technology & Devices Laboratory
Electronics Research and Development Command
Fort Monmouth, New Jersey 07703

Advanced Systems Division
LOCKHEED MISSILES & SPACE CO., INC.
1111 Lockheed Way
Sunnyvale, California 94086

3047

40

344 705

TABLE OF CONTENTS

<u>Section</u>	<u>Description</u>	<u>Page</u>
1.0	CONFERENCE	1
1.1	15 November 1979 at Fort Monmouth	1
2.0	INTRODUCTION	5
2.1	Background	5
2.2	Statement of the Problem	5
2.3	Technical Guidelines	6
2.3.1	Scope	6
2.3.2	Applicable Documents	6
2.3.3	Requirements	6
2.3.3.2	Detailed Program Objectives	6
3.0	TECHNICAL APPROACH	10
3.1	Proposed CRT	10
3.2	Thin Film Phosphor Faceplate	10
3.3	Color Optimization	13
3.4	Processing of the Aluminosilicate Glass Faceplate	13
3.5	Black Back Degradation During Sealing	13
3.6	Optimization of Sapphire Faceplates	14
3.7	Measurements of Faceplate Properties	14
3.8	Faceplate Fabrication	14
3.8.1	Cleaning of Substrates	15
3.8.2	Sputtering of Phosphor Films	15
3.8.3	Laser Thickness Monitor	15
3.8.4	Four-Inch Tube Furnace	15
3.8.5	Cathodoluminescence Measuring System	16
4.0	PROGRESS DURING REPORT PERIOD	17
4.1	Materials and Supplies Procurement	17
4.1.1	1710 Glass	17
4.1.2	1720 Glass	18
4.1.3	Sapphire Substrates	18
4.1.4	Miscellaneous	19

TABLE OF CONTENTS (Cont)

<u>Section</u>	<u>Description</u>	<u>Page</u>
4.2	Europium Optimization Study	19
4.3	Fabrication of Faceplates	19
4.4	Cathodoluminescence Brightness Measurements	21
4.5	Residual Sulfur Study	36
4.6	Literature Review	37
4.7	Delivery of Faceplates	38
5.0	CONCLUSIONS	38
6.0	PROGRAM FOR NEXT INTERIM PERIOD	39
7.0	REFERENCES	39
8.0	APPENDIX	40

LIST OF ILLUSTRATIONS AND TABLES

<u>Figure #</u>	<u>Description</u>	<u>Page</u>
1	Schematic of High Contrast CRT	11
2	Schematic of High Contrast Two-Color Screen	12
3	Cathodoluminescence, Faceplate 38	25
4	Cathodoluminescence, Faceplate 39	26
5	Cathodoluminescence, Faceplate 40	27
6	Cathodoluminescence, Faceplate 41	28
7	Cathodoluminescence, Faceplate 42	29
8	Cathodoluminescence, Faceplate 43	30
9	Cathodoluminescence, Faceplate 44	31
10	Cathodoluminescence, Faceplate 45	32
11	Cathodoluminescence, Faceplate 46	33
12	Cathodoluminescence, Faceplate 48	34
13	Cathodoluminescence Summary	35
A-1	Schematic of 5UP1 Gun	41
A-2	Deflection and Power Supply Circuit for 5UP1 Gun	42
A-3	Distortion of 1710 Glass Disc After 850 ⁰ C Treatment	43
A-4	Demountable Cathodoluminescence System	44
 <u>Table #</u>		
1	Faceplate Fabrication Summary	23
1-A	Anneal of Glass Discs	24
2	Cathodoluminescent Brightness	25
3	Sulfur Evaporation Rate	37

1.0 CONFERENCE

1.1 15 November 1979 at Fort Monmouth

Report of conference held at ERADCOM, Ft. Monmouth, New Jersey on 15 November 1979 with LMSC to review progress on Contract DAAK 20-79-C-0282, High Contrast CRT Faceplates:

Personnel Present:

LMSC, Inc.

Dr. R. A. Buchanan

Dr. T. G. Maple

ET&D Lab - ERADCOM

P. F. Krzyzkowski

Dr. Joel Shapiro

Donald C. Fox

The purpose of the meeting was to review and discuss progress under the recently awarded contract. This contract is a continuation of previous work at LMSC, a subcontractor to the Watkins-Johnson Company under Contract DAAB-07-77-C-2639. Much of the discussion focused on problems encountered under the previous program which have not yet been resolved.

1.1.1 Contract Documentation

P. Krzyzkowski noted that the technical guidelines need not be included in each report. Also, that it is desirable that photos which will be the basis for visual aids scheduled for delivery at the end of the contract be included in current reports. Appropriate subjects would be deposition and processing equipment, the demountable cathodoluminescent equipment, spectra, and other data. These photos need not be in color. Distribution list for reports will be provided by ERADCOM when the report draft has been approved.

P. Krzyzkowski will provide LMSC with a sample format for the monthly correlation report.

1.1.2 LMSC reported that fifty 6-1/2 x 6-1/2 in. x 4 mm plates of alumino-silicate 1710 glass have been ordered from Corning Glass. 1710 glass

is identical in composition and properties to 1720 glass, except for the addition of 17 ppm cobalt. Tests at LMSC have shown that the cobalt presents no problems. 1720 glass is no longer available in plate from Corning. Faceplate discs will be cut and polished by United Lens, Inc., Palo Alto, California.

The possibility that residual stress in the glass may be contributing to the distortion problem was discussed. It was agreed that LMSC will anneal some of the substrates prior to phosphor film deposition.

A supply of sapphire faceplates has been ordered by LMSC from Crystal Systems, Inc. Expected delivery is early January.

To expedite receipt of substrates, Corning has been requested by LMSC to drop ship direct to United Lens, Inc., the 1710 plates for cutting and polishing. LMSC will ask United Lens to see if strains are present in the plates. If so, annealing prior to grinding and polishing would be advisable.

LMSC will also discuss with United Lens whether the faceplate thickness can be increased some 0.015 in. to allow for subsequent removal of distortion without reducing finished thickness below 0.125 in.

1.1.3 Phosphor Deposition

The system presently used for phosphor deposition is downward RF sputtering from the oxysulfide target. Particles which may detach from the sintered target can produce pinholes in the film. This may be a factor in causing greater diffuse reflection than desired. This could be avoided by upward sputtering. Procurement of a new sputtering system would be required because the present system cannot be readily modified. This would entail a major fixed asset expenditure not provided for in the present contract.

1.1.4 Faceplate Processing

To improve phosphor brightness, the faceplates must be processed in an $H_2 + SO_2$ atmosphere at $870^{\circ}C$. Softening point of 1710 and 1720 glass is $915^{\circ}C$ according to Corning. Extensive distortion of the uncoated side of the faceplate has been observed at the $870^{\circ}C$ temperature. This

is attributed to stress produced by mismatch in expansion coefficients between the $\text{La}_2\text{O}_2\text{S}$ film ($80 \times 10^{-7}/^\circ\text{C}$) and the glass ($42 \times 10^{-6}/^\circ\text{C}$). Faceplates have been supported on vitreous carbon plates during treatment. No distortion was observed with faceplates supported on the original carbon plate, which was found to be bowed some .010 in. (concave). When this carbon plate developed a crack, it was replaced with a new vitreous carbon plate. The latter was lapped flat to eliminate a minor warping that occurred with the original carbon plate. All faceplates subsequently processed with the lapped carbon plate showed gross distortion, necessitating regrinding and polishing of the encoated side of the faceplates. No remedy presently exists for a minor warpage on the film side.

The distortion represents a major problem. It can be avoided completely by use of sapphire substrates, which provide a good coefficient match to the phosphor film. Sapphire would also permit processing at 1050°C for maximum phosphor brightness. The disadvantage is economic, sapphire substrates being some ten times as expensive as aluminosilicate glass.

Frit sealing of the aluminosilicate glass faceplates was discussed. Loss of hermeticity has been observed in assembled CRTs. Porosity of the seal is suspected. Numerous bubbles have been noted in the seal itself. Puncture of the thin bubble walls when a ground strap is placed around the seal area and anode potential applied to the tube appears to occur. Pre-bake of the frit coating before sealing may eliminate the bubbles.

A third problem noted by P. Krzyzkowski has been cathode poisoning when the tube is made operational. This problem was not observed with the initial faceplates made by LMSC. The possibility of contamination by elemental sulfur associated with the post-deposition treatment was considered. ERADCOM plans an RGA study using a monopole spectrometer for detection of sulfur. LMSC was requested to determine if a mass spectrometer study could be made at the Palo Alto Laboratory.

1.1.5 Black Layer Deposition Technique

Dr. Maple described the LMSC process for depositing the absorbing black layer (U.S. Patent 4,132,919). A graded V_2O_5 -V film is used in order to remain within maximum anode potential specified for the CRT.

1.1.6 Black Layer Degradation

The fourth major problem encountered has been degradation of the black layer during frit sealing of faceplates. Oxygen contamination of the inert gas atmosphere is suspected. The problem is compounded when cathode contamination occurs and the electron gun must be replaced.

ERADCOM plans to make an Auger and SEM study of the black layer.

1.1.7 Color Optimization

LMSC is preparing a series of $La_2O_2S:Eu$ phosphor powders covering an Eu concentration range of 1 to 15 a/m. Cathodoluminescent brightness and color coordinate measurements are planned to definitively establish the optimum europium concentration.

P. Krzyzkowski noted that the red color of the 6.5% Eu which has been used to date appears to be acceptable.

2.0

INTRODUCTION

2.1 Background

This program is a continuation of previous work at LMSC as a subcontractor to the Watkins-Johnson Company under Contract No. DAAB-07-77-C-2639 (see Research and Development Technical Reports ECOM-77-2639-1, Jan. 1978; ECOM-77-2639-2, May, 1978; DELET-TR-77-2639-3, Aug. 1979; DELET-TR-77-2639-4, Aug. 1979; DELET-TR-2639-5, Aug. 1979; and DELET-TR-77-2639-6.

The faceplates to be fabricated under this program are an essential component of the proposed high contrast multicolor CRT.

2.2 Statement of the Problem

The basic problem addressed by this program is the ability to display information generated by various electronic systems with suitable high resolution in two colors with its legibility maintained under ambient illumination ranging from 10^4 to 10^{-3} fc.

Existing color tubes cannot satisfy the above requirement. Such tubes which employ aperture masks are severely limited in brightness and resolution by the aperture mask. Their brightness is limited because the aperture mask transmission is only 15 to 20 percent, therefore wasting 80 to 85 percent of the current. The wide spacing between holes degrades the resolution below that required in most military systems. Furthermore, the color purity of such tubes is influenced by their position with respect to the earth's magnetic field, and it is therefore impractical to incorporate them in airborne systems.

The use of color penetration phosphors overcomes some of the problems of mask type tubes. The color purity is no longer affected by the tube orientation and the resolution is higher than that which can be achieved with a mask type tube. Conventional color penetration tubes which employ powdered phosphors cannot be used for daylight (high brightness) viewing because of their high reflectivity and low brightness, particularly in red, which produces a washed-out low contrast display. The reflectivity of the phosphor is high because of its particulate nature. The brightness of the red is low because most of the light generated by the red phosphor is scattered by the green phosphor before it reaches the faceplate of the CRT.

2.3 Technical Guidelines

2.3.1 Scope:

These technical guidelines outline a program leading to the design and fabrication of a very high contrast CRT. The screen phosphors of this CRT are to be transparent films backed by a black light absorption coating. The prime objective of this program is to optimize present transparent film phosphor technology and faceplate-envelope fabrication techniques for 3" CRTs and to investigate the application of this technology to larger CRTs. The phosphor screen is to incorporate a two layer, penetration type multicolor structure. The phosphored faceplate is to be attached to available tube envelopes in a manner consistent with economical CRT manufacturing methods.

2.3.2 Applicable Documents:

MIL-E-1 Manual

MIL-C-2505A (1963)

MIL-STD-1311A

2.3.3 Requirements:

2.3.3.1 General: This program shall be directed towards the optimization of a 3" high contrast CRT based on the use of high efficiency transparent phosphors. This capability is intended to be accomplished by the deposition of transparent phosphor layers on a suitable substrate that will be bonded to a standard CRT envelope in an economical manner. Optimization of phosphor efficiency, high color discrimination, the achievement of suitable red and green colors and refinement of sealing techniques shall be the prime objectives of this program.

Areas of investigation and performance objectives will include, but not necessarily be limited to, the features outlined in the following paragraphs.

2.3.3.2 Detailed Program Objectives:

2.3.3.2.1 Phosphor Screen Characteristics:

2.3.3.2.1.1 Physical Characteristics. A bilayer type of phosphor screen shall be used in the CRT. Each phosphor layer shall be transparent and may or may not be separated by a transparent dielectric layer.

2.3.3.2.1.2 Luminescent Material. A lanthanum oxysulfide host with proper rare earth activators to achieve the desired efficiency and colors shall be used.

2.3.3.2.1.3 Phosphor Persistence. The transparent phosphors used in the CRT screen should have persistence in the range of JEDEC designations "medium short" to "medium". Trade-offs of persistence with other phosphor properties and characteristics should be determined.

2.3.3.2.1.4 Phosphor Color. The red and green colors from the bilayer phosphor at their optimized anode voltages shall meet the color spectrum characteristics as described in MIL-C-25050A. The red color should be as pure as possible and should be optimized to meet the requirements of the above MIL Spec denoted as IPL red and use 6200\AA as a dominant wavelength. The green color should be optimized to meet the CIE coordinate specification limits as defined for Identification green.

2.3.3.2.1.5 Anode Voltage. The red and green colors defined in 3.2.1.4 shall be achieved at minimal anode voltage levels preferable not exceeding 10 kV (red) and 17 kV (green). Anode potential shifts to achieve the red and green and intermediate colors should be minimized.

2.3.3.2.1.6 Phosphor Efficiency. The energy conversion efficiency of the transparent phosphors shall be at least as good as that of the best corresponding powdered phosphors of the same general constituency.

2.3.3.2.1.7 Light Absorbing Layer. The phosphor screens shall be backed, on the electron gun side, with a uniform light absorbing coating that can be penetrated by the electron beam. Specular reflection from the phosphor light absorbing layer structure shall be no greater than 1% over the entire active area of the screen. Diffuse reflectance shall be no greater than 0.5% over the entire active area of the screen.

2.3.3.2.1.8 Black Layer Energy Loss. The black absorption layer characteristics shall be such as to minimize losses in the electron beam impingent on the phosphor. Maximum energy loss should be limited to 6 kV, although smaller losses are desirable. This shall be done consistent with 3.2.1.7.

2.3.3.2.1.9 Phosphor Electrode. The phosphor electrode shall be a thin aluminum film, behind the black coating of 3.2.1.7, and electrically insulated from all other tube electrodes by means sufficient to withstand the operating levels in the tube without electrical breakdown or appreciable current. The phosphor electrode film thickness shall be optimized to minimize energy loss to the phosphor screen.

2.3.3.2.1.10 Phosphor Screen Substrate. The phosphor screen substrate shall be capable of withstanding all necessary fabrication techniques of the transparent film screen without change of shape or curvature that would degrade the end result of a completed CRT. The important glass characteristics of the faceplate shall be at least as good of those of Corning Type 1720 glass. It is preferable that the faceplates be bonded to the tube envelope by conventional means (flame or frit seal) or use of graded seals. This program is not intended to support special envelope or glass seal development; however, glass to metal seal techniques may be considered as a last resort.

2.3.3.2.1.11 Phosphor/Black Layer Characteristics. The characteristics enumerated above should be completely assessed and evaluated in a demountable vacuum system.

2.3.3.2.2 CRT Characteristics. A laminar flow electron gun shall be used with this phosphor screen. The CRT shall be electrically interchangeable with the base pin connection of the Dumont 3055, and match the physical characteristics of that tube as well.

2.3.3.2.3 CRT Contrast. It is necessary that the CRT be legible in direct sunlight under its normal mode of operation, without the use of added contrast enhancement devices. Specific quantitative criteria to satisfy this requirement should be developed so that optical instrumentation tests may be used for its verification.

2.3.3.2.4 Resolution. A line width, taken at the half amplitude point of the spot distribution, of 0.012 inches or better is desirable. The line width should not exceed 0.016 inches.

2.3.3.2.5 Display Luminance. The CRT is to operate under ambient illumination from 10^4 to 10^{-3} fc. The CRT luminance is to be uniformly adjustable to provide satisfactory legibility under these conditions.

2.3.3.2.6 Display Brightness Uniformity. The CRT display brightness over the active viewable area, for any selected color and all colors, when operated at a set anode voltage for optimum color discrimination, shall be within $\pm 5\%$ of the average brightness determined over the screen, or as determined under dynamic writing conditions.

2.3.3.2.7 Writing Speed. A minimum writing rate of 50,000 in/sec for a single trace for all color fields is desirable.

2.3.3.2.8 Phosphor/Black Layer Maintenance. The phosphors/black layer are expected to have high maintenance. As a goal, the minimum operating time under the conditions enumerated in this technical guideline should be 3000 hours. Phosphor maintenance and burn sensitivity data shall be compiled and correlated to operating conditions. Early screening tests to determine acceptable completed faceplates should be developed.

2.3.3.2.9 Reliability Considerations. Since the CRTs developed under this program are intended for tactical and airborne applications, adequate consideration must be given throughout the development program to the reliability of this tube for such environments. As an objective, the CRT should be able to pass the physical tests for CRTs specified in MIL-E-1.

2.3.3.2.10 CRT Operational Characteristics. The electrical and optical operational characteristics of the CRTs shall be fully documented.

3.0

TECHNICAL APPROACH

3.1 Proposed CRT

Figure 1 is a schematic of the proposed high contrast multicolor CRT. The physical dimensions are identical with those of the existing CRT (Dumont KC3055). The phosphor screen incorporates a black backed multilayer bicolor transparent phosphor film deposited on a transparent substrate which is bonded to the CRT funnel and constitutes the faceplate of the CRT. The details of this faceplate are described further in this report. In operation, the color of the display can be controlled by selection of the beam potential. At about 10 kV, the display will be red, at 15-20 kV the display will be green. With the exception of the focus and anode potentials, the operating voltage will be same as the existing CRT.

3.2 Thin Film Phosphor Faceplate

Figure 2 is a schematic representation of the two-color high contrast faceplate to be fabricated under this program. As shown in the illustration, the two-color phosphor is supported on a transparent substrate which forms the faceplate of the CRT.

The green-luminescent film is immediately adjacent to the substrate. The red luminescent film resides on top of the green one. The absorbing nonreflective layer is next deposited on top of the red phosphor film. Finally, a thin conductive aluminum layer is deposited over the absorbing layer. In operation, the red phosphor layer absorbs most or all of the electron beam energy at potentials below 10 kV. At high potentials, for example, at 20 kV, most of the electron beam is absorbed in the green phosphor. At intermediate potentials, some electrons are absorbed by both layers, depending upon the exact value of the potential. (A mathematical description of the optimum film thickness is given in the proposal). Therefore, at low beam energies, only the red phosphor is excited and the display appears red. At high beam energies, the green-luminescent material is more excited and the display appears green. Various mixtures of the two colors are obtained at intermediate values of the potential. Note that since the luminous efficiency of the red is much lower than that of the green, it is important that the red be placed closest to the electron gun to prevent color contamination of the red by the green. If the green film were

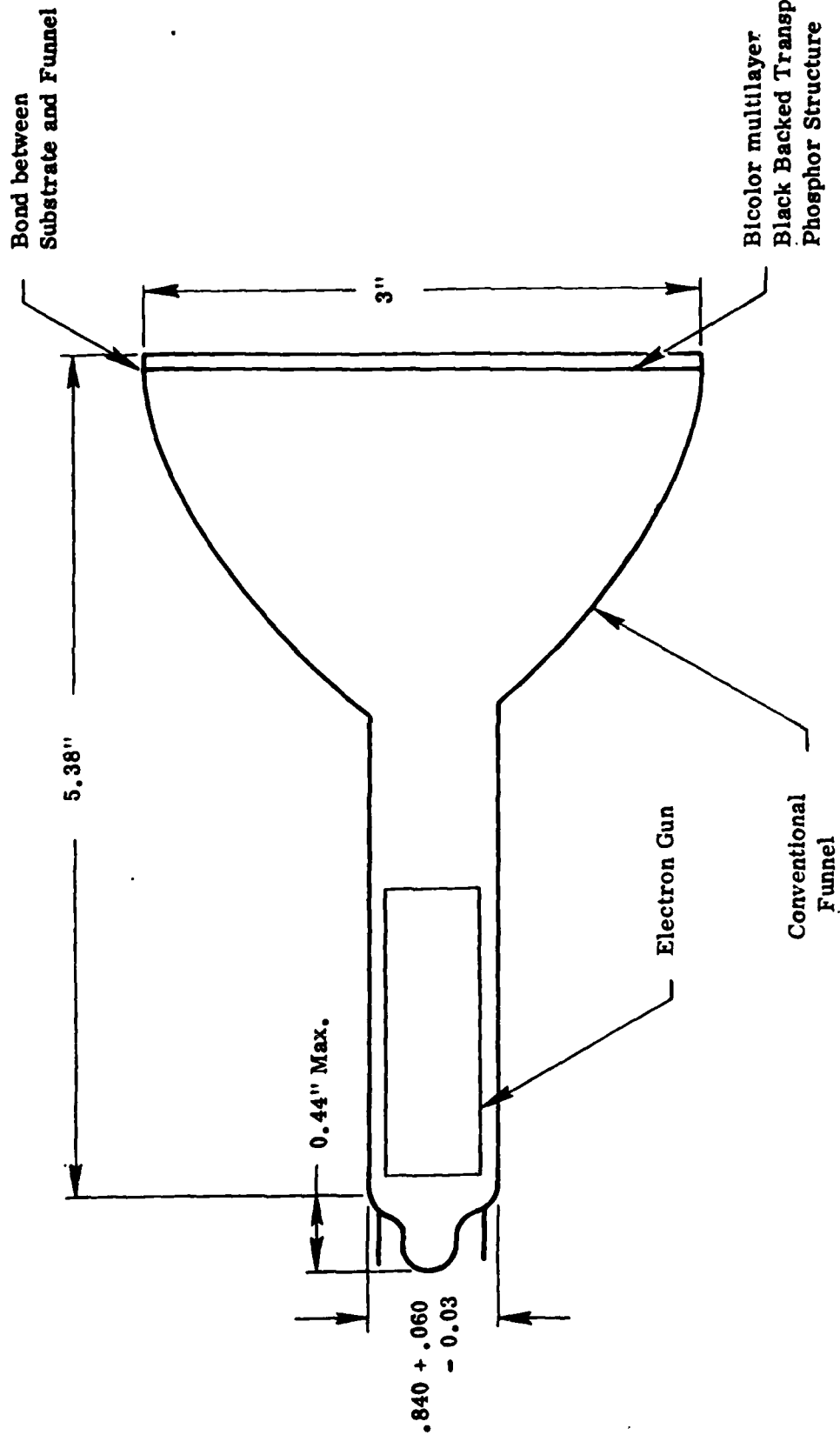


Figure 1. Schematic of High Contrast CRT

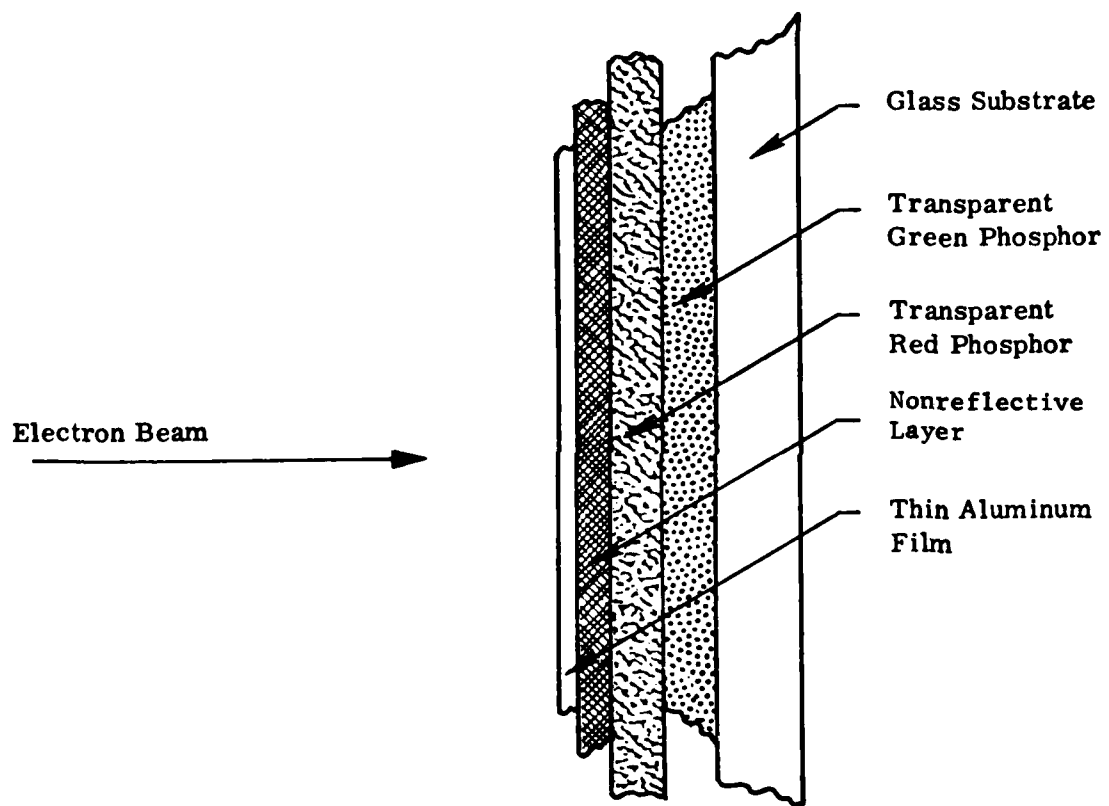


Figure 2. Schematic of High Contrast Two-Color Screen

closest to the gun, it would not be possible to excite the red without getting some color contamination from the green phosphor.

3.3 Color Optimization

It is planned that a study of red color coordinates will be completed for different europium concentration levels during the present program. It is proposed that a sputtering target of the optimized europium concentration be fabricated and bilayers of the optimized red color be evaluated.

The color coordinates and the light output are variables which interface with each other. The trade-off between these variables will be measured.

The green color coordinates are affected primarily by the excitation potential. The trade-offs between the green color coordinates and excitation potential will also be measured in order to optimize the green emission. This may also involve the thickness of the black back, the red $\text{La}_2\text{O}_2\text{S:Eu}$ layer, and the aluminum layer as well.

3.4 Processing of the Aluminosilicate Glass Faceplates

It has been determined that conditions in the processing treatment phase can degrade the clarity of the 1720 glass substrate. Varying the treatment conditions can reduce or increase film luminescent efficiency. Studies will be undertaken to determine optimum conditions for obtaining the highest luminescent efficiency consistent with maintaining the optical quality of the substrate. Variables which are expected to affect these properties include: (1) the support for the glass in the treatment furnace; (2) the treatment temperature; (3) the rate of cooldown after treatment, and (4) the rate of flow of reaction gases during treatment.

3.5 Black Back Degradation During Sealing

During the previous program, it had been determined that some degradation of the black back nonreflective layer may be occurring during the process of sealing the faceplate to the funnel. This degradation may be caused by migration of ions within the inhomogeneous nonreflecting layer as a result of the high temperature experienced by the layer during the sealing process. (It is unknown at this time if this high temperature process also affects the efficiency of the luminescent layer). This degradation will be measured to determine if this effect will be detrimental to the overall performance of

the CRT. Ways of reducing the degradation will be studied if required.

3.6 Optimization of Sapphire Faceplates

The process for making the sapphire faceplates will be reinstituted in our laboratory and sapphire faceplates fabricated for the first time in several years. The luminescent efficiency of the sapphire faceplates will be compared with that of the 1720 glass faceplates. It may be possible to achieve a higher efficiency for sapphire faceplate luminescence due to a higher possible processing treatment temperature. These comparative efficiency measurements may provide direction for future work on this program.

3.7 Measurements of Faceplate Properties

At the present time, no standards of measurements of high-contrast faceplate performance exist. This is a fundamental problem which needs to be considered in order to achieve a satisfactory means of evaluation of these items at different facilities. The measurements presently being made, e.g., specular reflectivity and light output from a small raster excitation are meaningful only for relative comparison of faceplates at our facility. This is, of course, meaningful data, but its relation to the ultimate performance of the faceplate in the CRT is unclear.

Consideration will be given to the problem of measuring both the specular and diffuse reflectivity of the faceplate. Diffuse reflectivity as a function of angle will be investigated. Specular reflectivity as a function of wavelength will also be investigated.

An attempt to define measurements which establish the performance properties of the CRT when used in practice will be considered.

While these new measurement techniques are being investigated, measurements of faceplate properties as described in our previous proposal will be continued and data from these measurements delivered with the faceplates.

3.8 Faceplate Fabrication

The procedure for fabricating the faceplates and measuring their cathodoluminescent brightness has been previously described in detail (Ref. 1). Only modifications which have been found desirable will be discussed here.

3.8.1 Cleaning of Substrates

It has been found that aluminosilicate glass is susceptible to etching when subject to hot saturated chromic acid cleaning solution. This step has been eliminated, and cleaning in ultrasonic agitated Alconox detergent solution substituted. Rinsing and final immersion in isopropyl alcohol before drying remain as before.

3.8.2 Sputtering of Phosphor Films

In the present system, the oxysulfide phosphor film is deposited in the downward direction from a pressed and sintered 5 in. target onto the substrate placed below the target. This has been found to have the disadvantage that fine particles which may be dislodged from the target settle onto the substrate. Such particles make further deposition of phosphor film, resulting in pinholes in the film. The particle discontinuities in the film are capable of scattering incident ambient light, producing an increased diffuse reflectance which is detrimental to contrast.

The pinhole defects can be eliminated by improved sputtering from a target placed below the substrate. LMSC plans to acquire an upward sputtering module during the period of this program. The faceplates to be delivered during the latter part of the contract period will be fabricated using the upward sputtering module.

3.8.3 Laser Thickness Monitor

The laser thickness monitor has been found to produce erratic results due to RF pickup by the 741 op amp. The RF pickup appears to enter via the regulated DC supplies used for the 741 op amp. Shielding of the DC leads was ineffective; the DC supplies have therefore been replaced with 9V batteries placed within the op amp enclosure.

3.8.4 Four-Inch Tube Furnace

It was found necessary to replace one of the controllers for the four-inch tube furnace used for the $H_2 + SO_2$ treatment to optimize the oxysulfide film luminescent brightness. The age of the furnace is such that further component failure can be anticipated. LMSC plans to replace this furnace with a 6-inch multi-tube furnace during the present year. This will permit 5-inch dia.

faceplates to be treated and also increase productive capacity.

3.8.5 Cathodoluminescence Measuring System

The vacuum portion of the demountable cathodoluminescence system has been rebuilt. The 4-inch diffusion pump was replaced with a 6-inch diffusion pump; the trap was replaced with a long persistence, anti-creep trap from Circuits Processing Apparatus, Inc. A single filling of the trap suffices for more than 8 hours; in fact, the system can be left under high vacuum overnight, improving the electron gun cathode life.

The electronics of the measuring system was completely rebuilt. Improvement in performance was not as great as expected. This was traced to a combination of the characteristics of the 5UP1 electrostatically deflected electron gun and its enclosure in a metal tube. The metal tube has an adverse effect on the potential lines in the vicinity of the gun. This has been partly improved by adding an accelerator tube made of copper shim stock, connected to grid No. 2 potential and positioned to surround the deflection plates. The accelerator was insulated from the outer metal tube by a thin Mylar tube. Schematics of the 5UP1 gun and the electronic circuitry are shown in the Appendix (see Figures A-1 and A-2, respectively). A better solution would probably be to replace the 5UP1 with a magnetically deflected, glass enclosed gun. A source of such guns is currently being sought. Improved deflection characteristics and much higher screen currents may be possible by replacement of the gun.

The demountable cathodoluminescence system is shown in Figure A-4 (see Appendix).

4.0

PROGRESS DURING REPORT PERIOD

4.1 Materials and Supplies Procurement

4.1.1 1710 Glass

A quantity of Code 1710 aluminosilicate glass in the form of pressed plates 6-1/2 x 6-1/2 in. x 4 mm was ordered from the Corning Glass Works. The 1720 glass previously used for fabricating faceplates was no longer available from Corning. Corning presently manufactures 1720 glass only in tube form.

Although tube diameters are large enough to permit cutting 3 in. dia. discs from longitudinally sliced and flattened tubing, thickness is insufficient for faceplate requirements. We were also informed by Corning that the furnace used for 1720 tube glass melts is not equipped with stirring devices so that flat plates produced from the melt would contain numerous bubbles rendering the glass translucent rather than transparent. Resultant light scattering would defeat the purposes of this program. The furnace originally used to product 1720 glass plates apparently no longer exists.

It was learned that a quantity of Code 1710 glass plates were in Corning's inventory. 1710 glass is identical in composition and properties to 1720 glass, except for the addition of 17 ppm cobalt. An $\text{La}_2\text{O}_3\text{:S:Tb}$ film was deposited on a sample of 1710 glass, then treated at 850°C in $\text{H}_2 + \text{SO}_2$ to improve the phosphor cathodoluminescence. The presence of the small amount of cobalt produced no adverse effect; it was therefore decided to use 1710 glass for this program.

Delivery of the 1710 glass was expected in early October. However, we were then informed by Corning that the plates were badly warped and required flattening before shipping. A shipping date of 1 November was then promised. The warpage had not been evident in the sample received in June, 1979. In explanation, Corning stated that the sample was the "best of the lot". Drop shipment from Corning directly to United Lens, Inc., for cutting and polishing was requested in order to save time and permit phosphor deposition to be started as soon as possible.

Corning then assured LMSC that the 1710 glass plates would be flattened and drop shipped to United Lens, Inc., on November 10. This commitment was not met. Upon inquiry, Corning stated that they had difficulty flattening the plates and that nolehr was available for annealing the glass.

United Lens, Inc., was then asked whether they could handle the flattening and annealing. They replied they saw no problems. Corning was therefore instructed to ship the glass to United Lens. The plates were actually not delivered at United Lens until November 26.

Thirty 3 in. dia. cut and polished substrate discs of 1710 glass were received from United Lens, Inc., on December 11. No evidence of stress was detected when examined with polarized light.

Forty-four 6-1/2 x 6-1/2 plates of 1710 glass remaining from the quantity drop shipped by Corning directly to United Lens were also returned by the latter, together with twelve approximately 2 x 3 in. pieces of cutting scrap. The scrap pieces are useful as test specimens.

4.1.2 1720 Glass

The delay in shipment of the 1710 glass by Corning meant that there would be insufficient time for fabrication and characterization of the entire lot of faceplates scheduled for mid-January delivery to ERADCOM.

Inquiry was made of Watkins-Johnson Company whether they had any 1720 glass discs remaining on hand. Arrangements were made to obtain 8 discs of 1720 glass from them.

4.1.3 Sapphire Substrates

The 3-in. dia. x 1/8" thick sapphire orientation 60° to C-axis, substrates required for this program were ordered from Crystal Systems, Inc., Salem, Mass., on October 19, 1979. The promised delivery date of January 10, 1980 was not met due to trouble with their suppliers, according to Crystal Systems, Inc. They now promise delivery of 6 substrates on March 1, and the remaining 20 on April 1, 1980.

4.1.4 Miscellaneous

The various gases required for processing the phosphor films were ordered and received. Alumina plates to support the sapphire discs during the sulfurization treatment were procured from Material Research Corporation, Orangeburg, New York.

4.2 Europium Optimization Study

A series of lanthanum oxide samples containing 1, 1.5, 2.5, 3.5, 5, 6.5, 8, 10, and 15 percent Eu were prepared by co-precipitation of the oxalates and subsequent calcination. The nine La_2O_3 :Eu samples were then converted to $\text{La}_2\text{O}_2\text{S}$:Eu. Cathodoluminescent brightness and color coordinate measurements will provide the necessary information to determine the optimum Eu concentration for the red film of the faceplates. A new $\text{La}_2\text{O}_2\text{S}$:Eu sputtering target of this composition will then be obtained.

The measurements were delayed when it was found necessary to redesign the electronics of the demountable system in order to eliminate problems with high voltage breakdown and poor control of electrical bias.

Also, it was found that the grid currents comprised as much as 90 percent of cathode emission current, so a separate means of accurately measuring the screen current was incorporated. This work was not completed until the last workday prior to the Christmas holiday week. Despite this effort, the maximum screen current obtainable was found to be 5 microamperes, with a cathode current of 50 microamperes. Further improvement is clearly necessary.

To avoid further delay in delivery of the initial lot of 8 faceplates, measurements on the europium concentration samples were deferred until measurements had been completed on the initial lot of faceplates. It is expected that the europium measurements can be completed by February 15.

4.3 Fabrication of Faceplates

Thirteen aluminosilicate glass discs were used for fabrication of the initial lot of faceplates. Eight of these were 1720 glass obtained from Watkins-Johnson Co; two were 1710 discs that had been previously cut from the sample

received from Corning in June. These were supplemented by three 1720 discs on hand in-house.

Several of the discs were annealed at temperatures of 870, 800, or 750°C prior to deposition of the phosphor film to ascertain whether annealing would reduce the distortion which had been encountered during the post deposition treatment at 870°C in $H_2 + SO_2$. Although no patterns were seen under polarized illumination, it was felt that the discs might still contain some stress.

Bi-layer $La_2O_3S:Tb-La_2O_3S:Eu$ films were then deposited on the substrates, followed by treatment in $H_2 + SO_2$ at 850°C. Distortion of the uncoated glass sides was evident on all discs, see Figure A-3 in Appendix, although not as extensive as previously experienced. This may have been due to a possible difference in actual furnace temperature. The thermocouples previously used to calibrate the furnace were found to disagree substantially from standard e.m.f. tables, one couple indicating a temperature 50°C higher than standard, the other couple 25°C lower than standard. A new, inconel-sheathed thermocouple was obtained from Omega, permitting accurate furnace calibration using a laboratory millivolt potentiometer. The inconel sheath will protect the couple from possible adverse effects of S or SO_2 .

Periodic calibration of the furnace is desirable as a check on possible change of the characteristics of the Pt-Pt 13% Rh thermocouples in the automatic temperature control circuitry due to ageing or possible traces of sulfur vapors in the laboratory atmosphere.

No conclusion can presently be drawn whether annealing of the glass discs is effective in reducing distortion.

In addition to the distortion of the uncoated side, some warpage of the film side was evident. It is not apparent whether a means can be found to eliminate the warpage.

Two faceplates were found frosty after the sulfurization treatment. A third was reserved for the residual sulfur study.

To eliminate a possible elemental sulfur contaminant, the faceplates were then baked in high vacuum at 350°C. To remove the distortion which occurred

during the $H_2 + SO_2$ treatment at $850^\circ C$, ten of the faceplates were sent to Diffraction Optics, Palo Alto, for repolishing of the glass side. The faceplates were returned on January 17, instead of the promised January 11 date. One faceplate was found returned badly chipped, and another had deep pits which could not be removed.

A further delay in completing fabrication of the initial lot of 8 faceplates was encountered when the forepumps of both the cathodoluminescence and sputtering systems failed. The consequent rise in fore-pressure resulted in oxidation and polymerization of the oil in the diffusion pumps, necessitating dismantling and thorough cleaning of both systems.

Following restoration of the vacuum systems to satisfactory operation, the vanadium NR films were deposited. The deposition schedule was modified slightly to ensure complete opacity of the NR films. Some additional vanadium film samples were prepared on glass slides and sent to P. K. Krzyzkowski for Auger analysis at ERADCOM.

Fabrication of the 8 faceplates was completed by deposition of 800\AA of aluminum. The faceplate fabrication conditions are summarized in Table 1.

Additional details of annealing the glass discs prior to phosphor film deposition are shown in Table 1-A. The Poco densified carbon plates showed surface grind chatter marks. To remove these, the plate was lapped successively with 5 micron, then 1 micron alumina. Although the appearance was much improved, the annealed disc still showed graininess that appeared due to pick up of carbon grains by the glass. The remainder of the discs were annealed on the vitreous carbon plate which was free of this problem.

4.4 Cathodoluminescence Brightness Measurements

Cathodoluminescence (CL) brightness measurements were made on ten faceplates. Results of the measurements are summarized in Table 2. Plots of CL brightness in foot-lamberts vs. screen keV at $5\text{ }\mu A$ screen current are presented in Figures 3-12. A new Spectra Pritchard Model 1980A photometer was used for the measurements. This model has different aperture range than the Model 1970 previously used. The raster size at TV rate was $0.1 \times 0.1\text{ cm}$ as

compared to the 0.0238 cm^2 raster area previously used. The 6' aperture was used in the present measurements. Sawtooth-shaped signals at 30 Hz (vertical) and 15.75 KHz (horizontal) were applied to the deflection plates to generate the raster. Current density (0.5 mA/cm^2) for the present measurements was thus 2.38 times that previously used. The measured brightness values are accordingly greater by the same factor.

No data or CL figure is shown for Faceplate No. 47, because the faceplate was frosty after the $\text{H}_2 + \text{SO}_2$ treatment; as this would have resulted in an unacceptably large diffuse reflectance, this faceplate was removed from the lot.

CL data is shown for Faceplate No. 38 both before and after depositing an 800\AA layer of aluminum. The greater scatter in the nonaluminized points may be due to charging effects which do not occur in the presence of the conducting aluminum layer.

Inspection of Table 2 shows some large differences in CL brightness at 10 Kev between faceplates (No's 40 and 46, for example). During the course of the measurements, it was observed that the spot size was affected by a change in value of the screen potential. To correct for this, it was found necessary to refocus after each change of screen potential. Moreover, the spot was poorly defined even at the best focus. In consequence, the individual raster lines were not distinguishable.

The deficiencies of the present CL measuring system can be summarized as follows:

1. Poorly defined spot
2. Maximum raster $0.1 \times 0.1 \text{ cm}$
3. Maximum screen current 5 microamperes.

For the purposes of this program, the CL measuring system must be modified to meet the these objectives:

1. Well-defined spot .016 in. in diameter
2. Raster $1\text{-}1/4 \text{ in.} \times 1\text{-}1/4 \text{ in.}$
3. Screen current 200 - 500 microamperes.

Table 1
Faceplate Fabrication Summary

F. P. No.	Glass Type	Anneal °C	La ₂ O ₃ :Sb Run No.	Min.	La ₂ O ₃ :Eu Run No.	Min.	H ₂ +SO ₂ °C	Vac. Bake °C	Min.	NR(V) Run No.	A ₁ °A	Remarks
38	1720	No	20-79	120	4-79	55	830	350	60	11-80	800	
39	1720	No	21-79	124	5-79	55	850	350	60	12-80	800	Chipped
40	1720	870	22-79	120	6-79	55	850	350	60	13-80	850	
41	1720	870	23-79	121	7-79	55	850	350	60	14-80	800	
42	1720	870	24-79	122	8-79	55	850	350	60	15-80	800	
43	1720	870	25-79	130	9-79	55	850	350	60	16-80	830	Deep pits
44	1720	870	26-79	124	10-79	55	850	350	60	17-80	800	
45	1720	870	27-79	120	11-79	55	850	350	60	18-80	800	
46	1720	870	28-79	120	12-79	55	850	350	60	19-80	800	
47	1720	844	29-79	120	13-79	55	850	350	60	-	-	Frosty
48	1720	No	30-79	120	14-79	55	850	350	60	20-80	800(?)	
49	1710	No	31-79	120	15-79	55	870	350	60	-	-	Frosty
50	1710	750	32-79	125	16-79	55	870	-	-	-	-	Frosty S Test
(?)	Monitor Defect											

LMSC-D766118

Table 1A
Anneal of Glass Discs

Faceplate No.	°C	Min.	Support	Other	Remarks
38	-	-			
39	-	-			
40	870	60	PC	Slow Cool	Grainy + Defects
41	870	60	Vit C	Slow Cool	
42	870	60	PCL		Less Grainy
43	870	60	Vit C		
44	870	60	"		
45	870	60	"		
46	844	60	"		
47	-				
48	-				
49	-				
50	750	60	"		

PC - Poco* Densified Carbon Plate

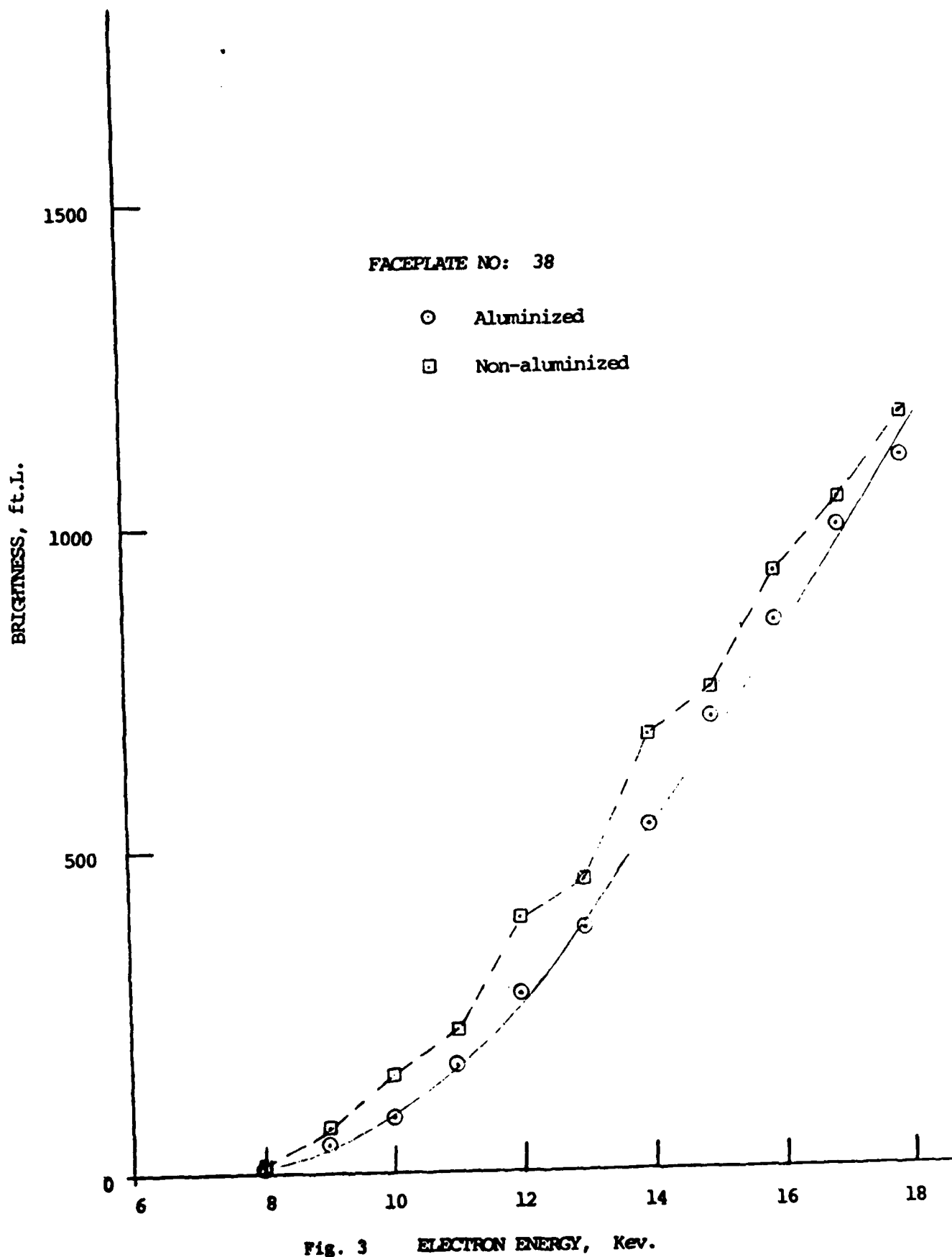
PCL - Poco Densified Carbon Plate, Lapped

Vit C - Vitreous Carbon Plate

* Poco Graphite, Inc., Garland, Texas

Table 2
Cathodoluminescent Brightness, FL
Faceplate No.

KeV	38	39	40	41	42	43	44	45	46	48
8	16.3	3.33	8.16	5.81	4.76	2.70	4.96	4.71	5.90	3.36
10	83.7	44.6	46.1	63.3	52.5	48.1	66.7	70.1	87.6	51.8
12	277	178	288	247	286	180	237	222	207	183
14	534	440	658	457	451	364	545	440	434	469
16	841	861	1037	729	861	954	873	830	823	906
18	1091	1108	1593	1226	1210	1434				1393



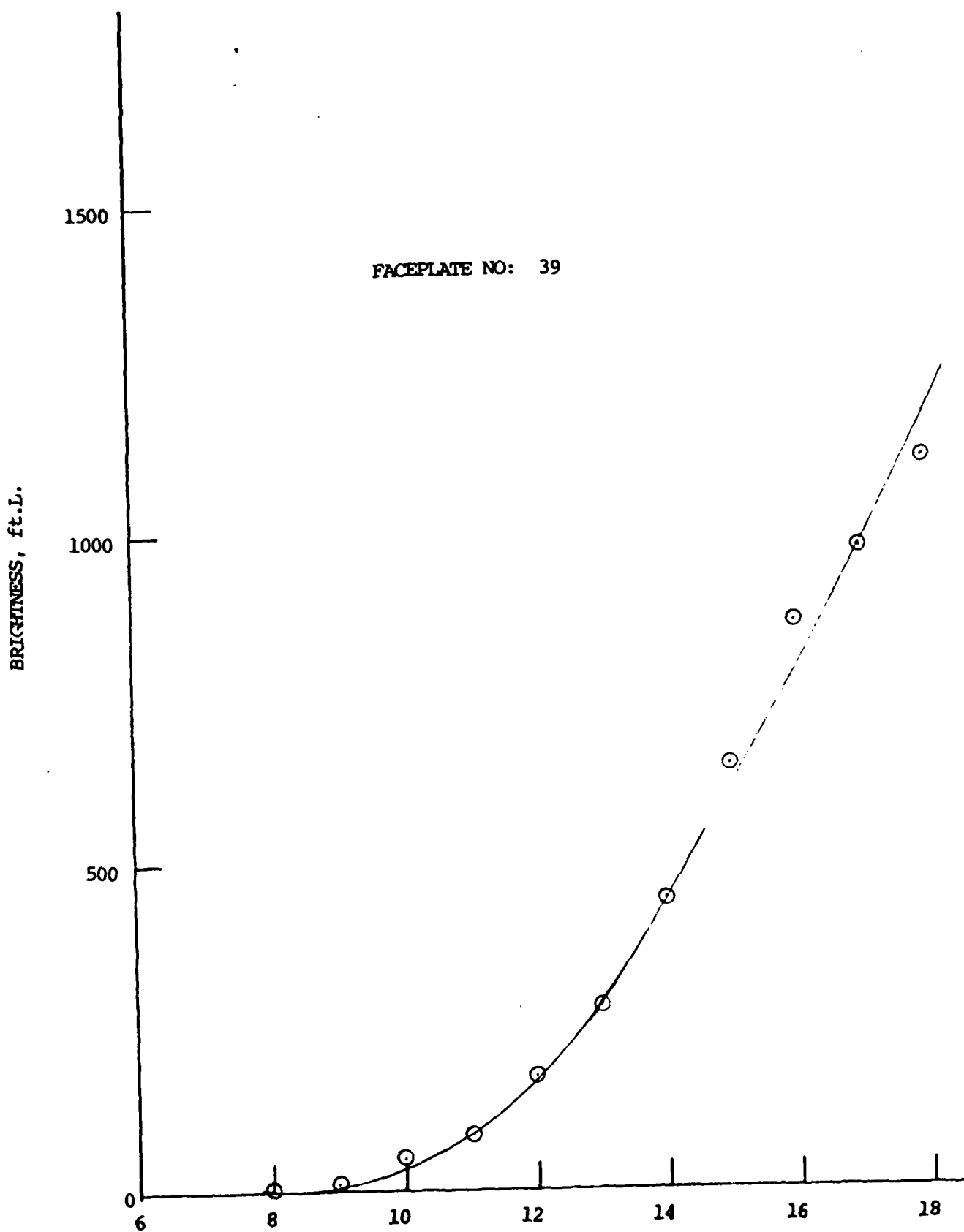


Fig. 4 ELECTRON ENERGY, Kev.

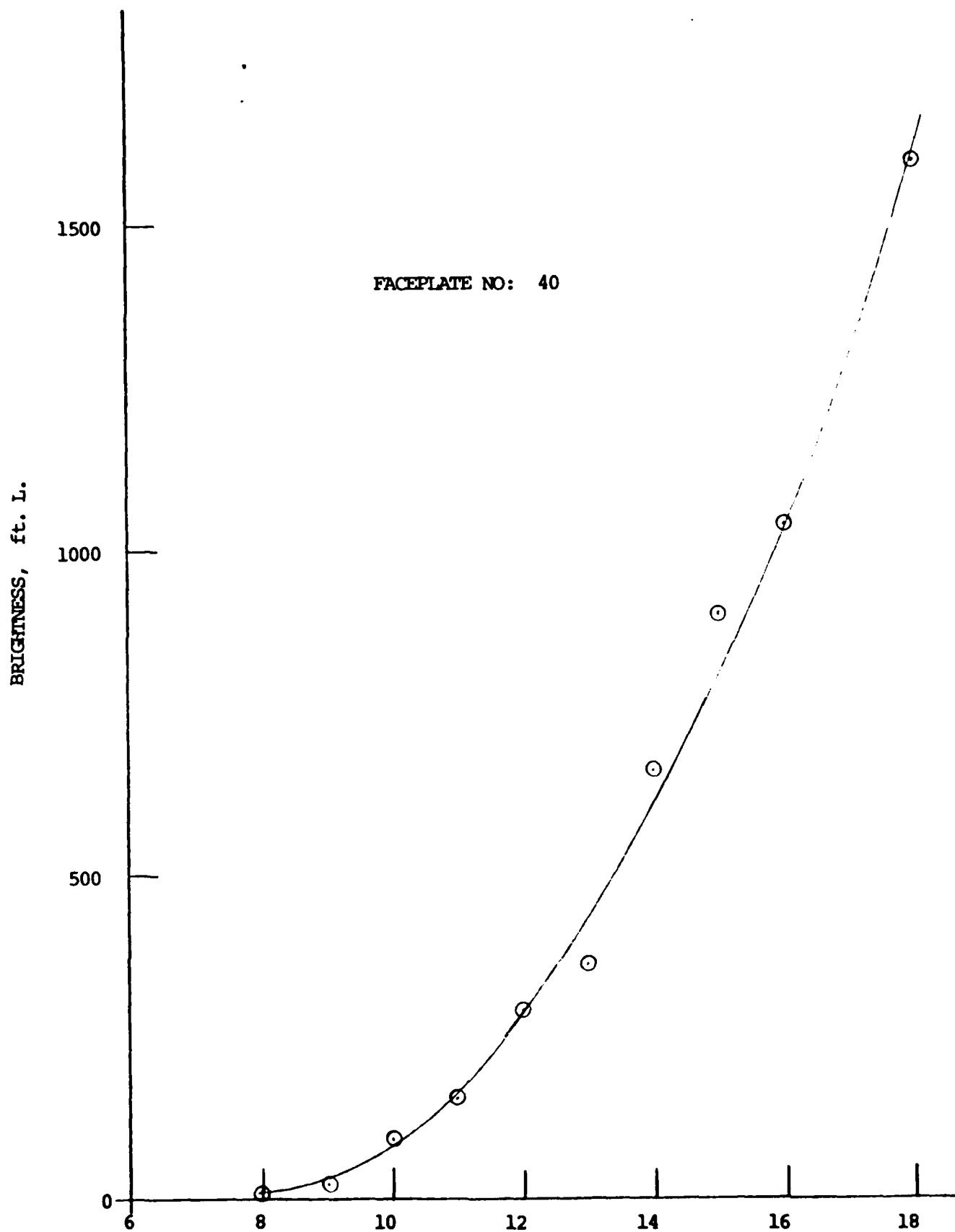


Fig. 5 ELECTRON ENERGY, Kev.

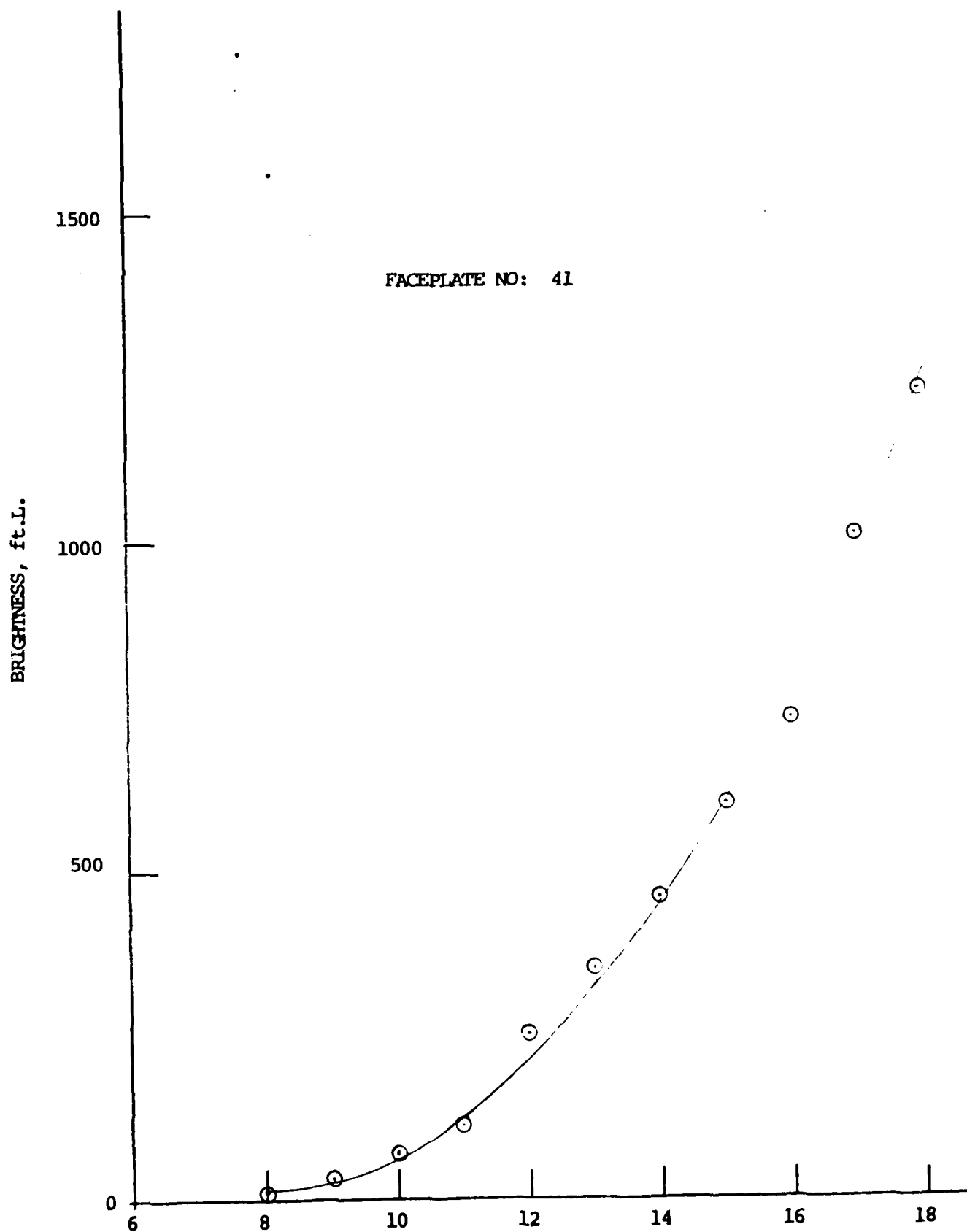


Fig. 6 ELECTRON ENERGY, Kev.

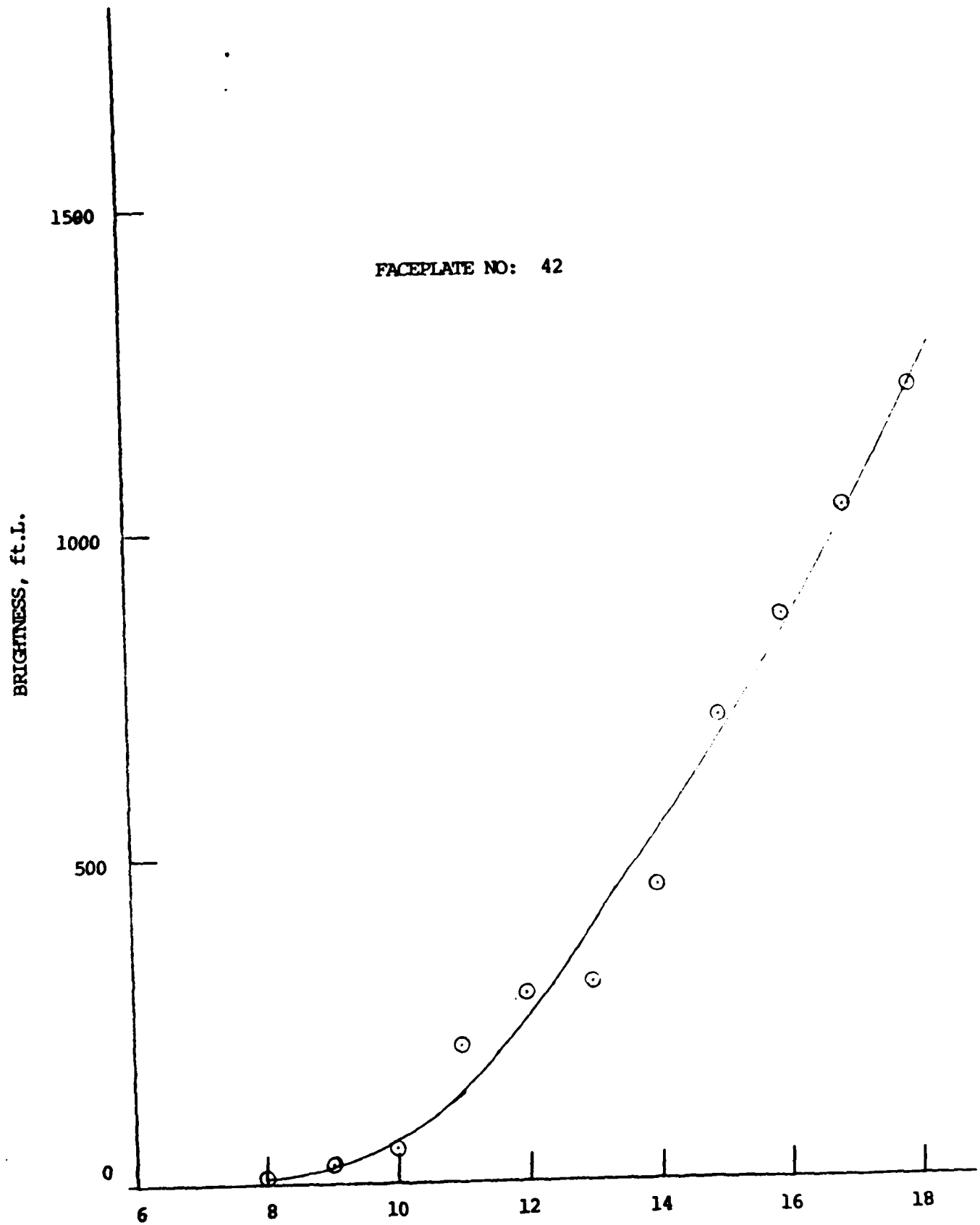


Fig. 7 ELECTRON ENERGY, Kev.

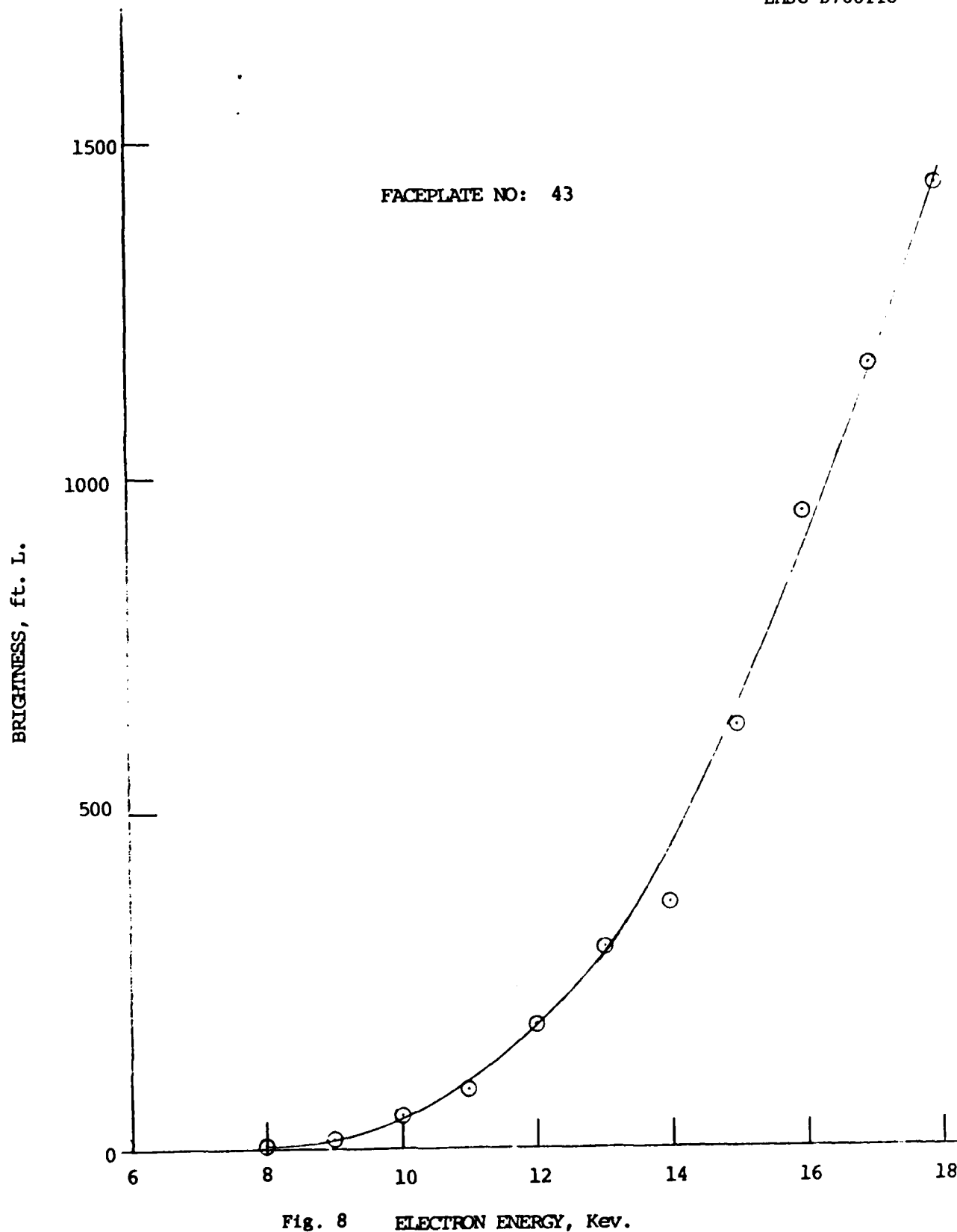


Fig. 8 ELECTRON ENERGY, Kev.

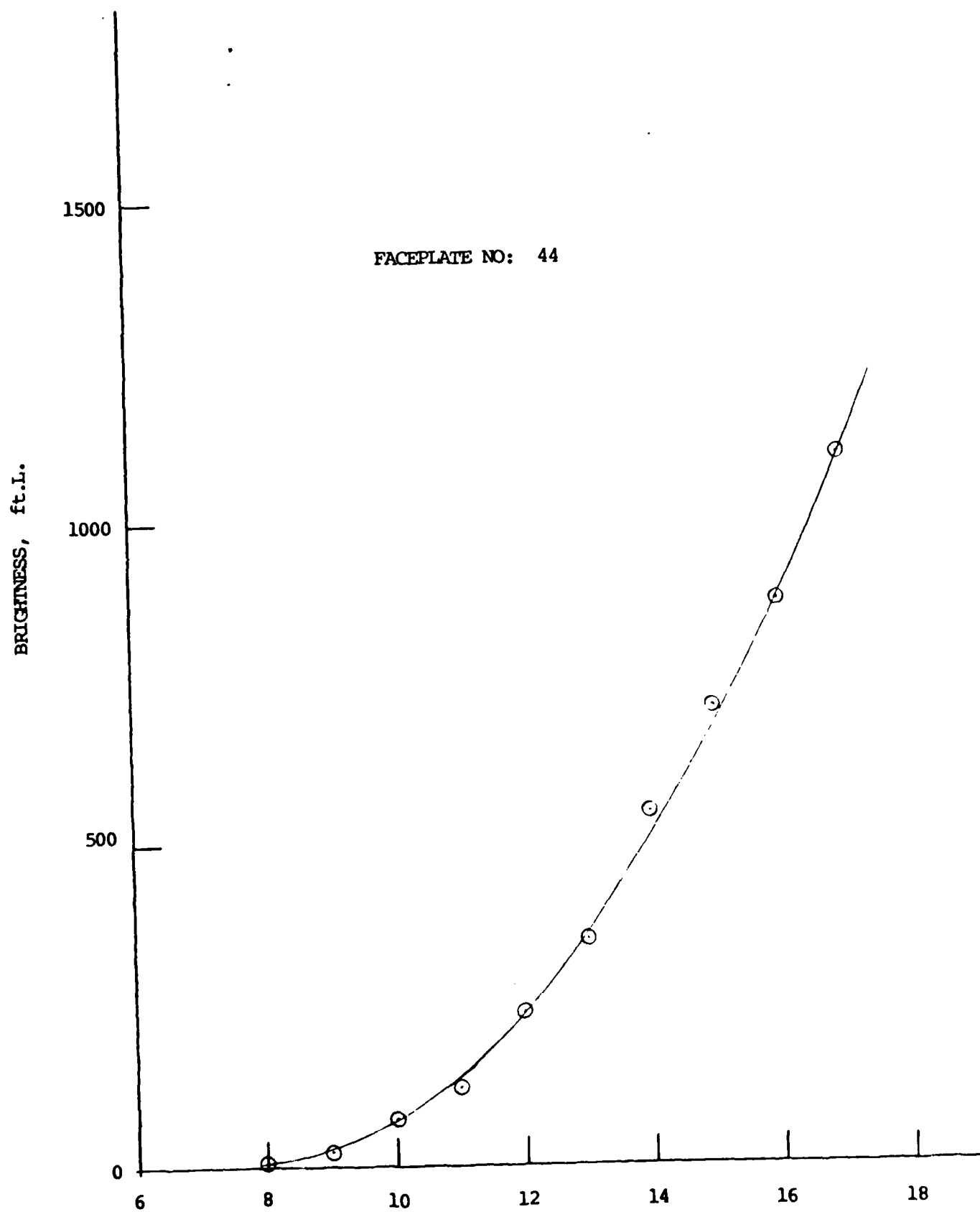


Fig. 9 ELECTRON ENERGY, Kev.

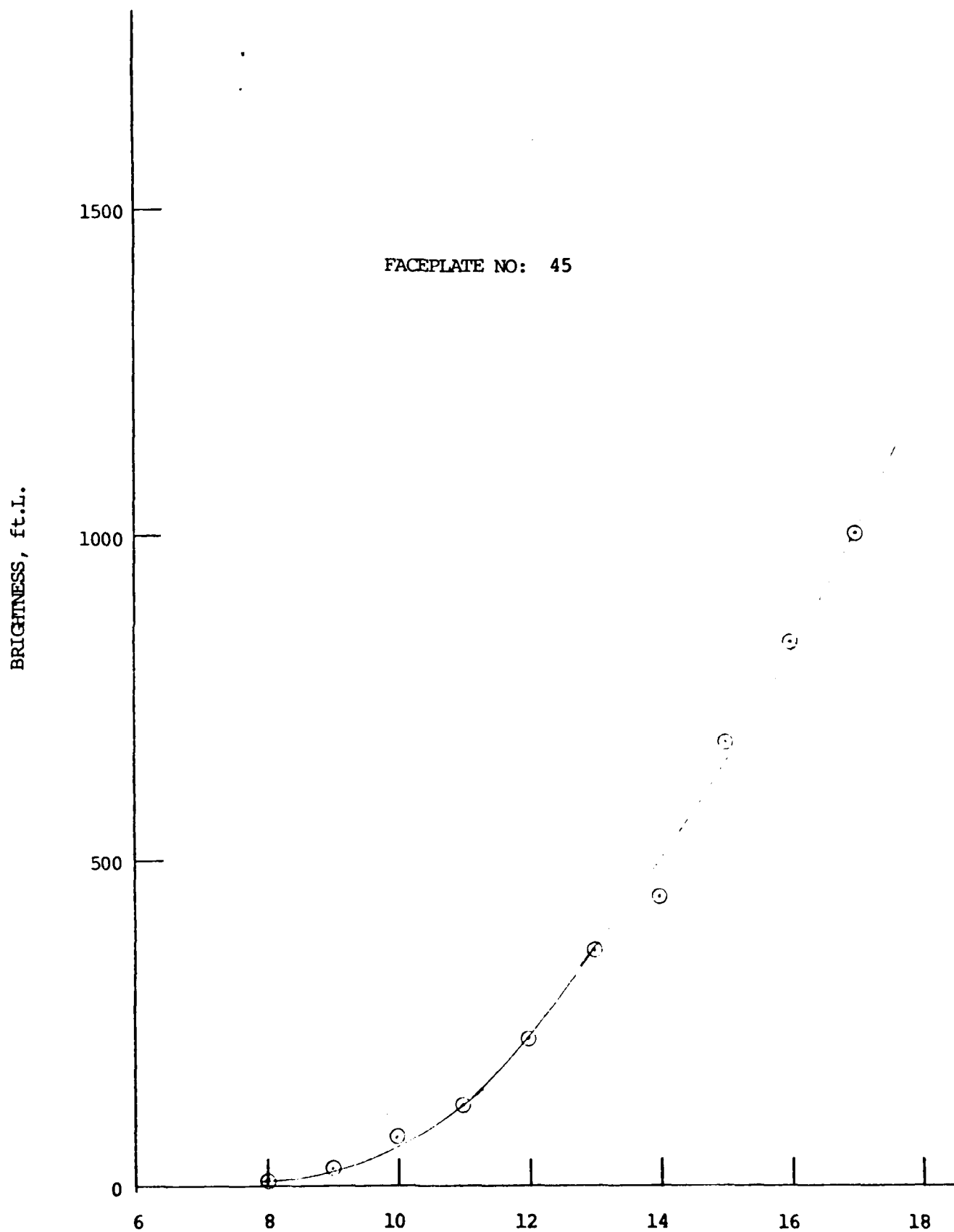


Fig. 10 ELECTRON ENERGY, Kev.

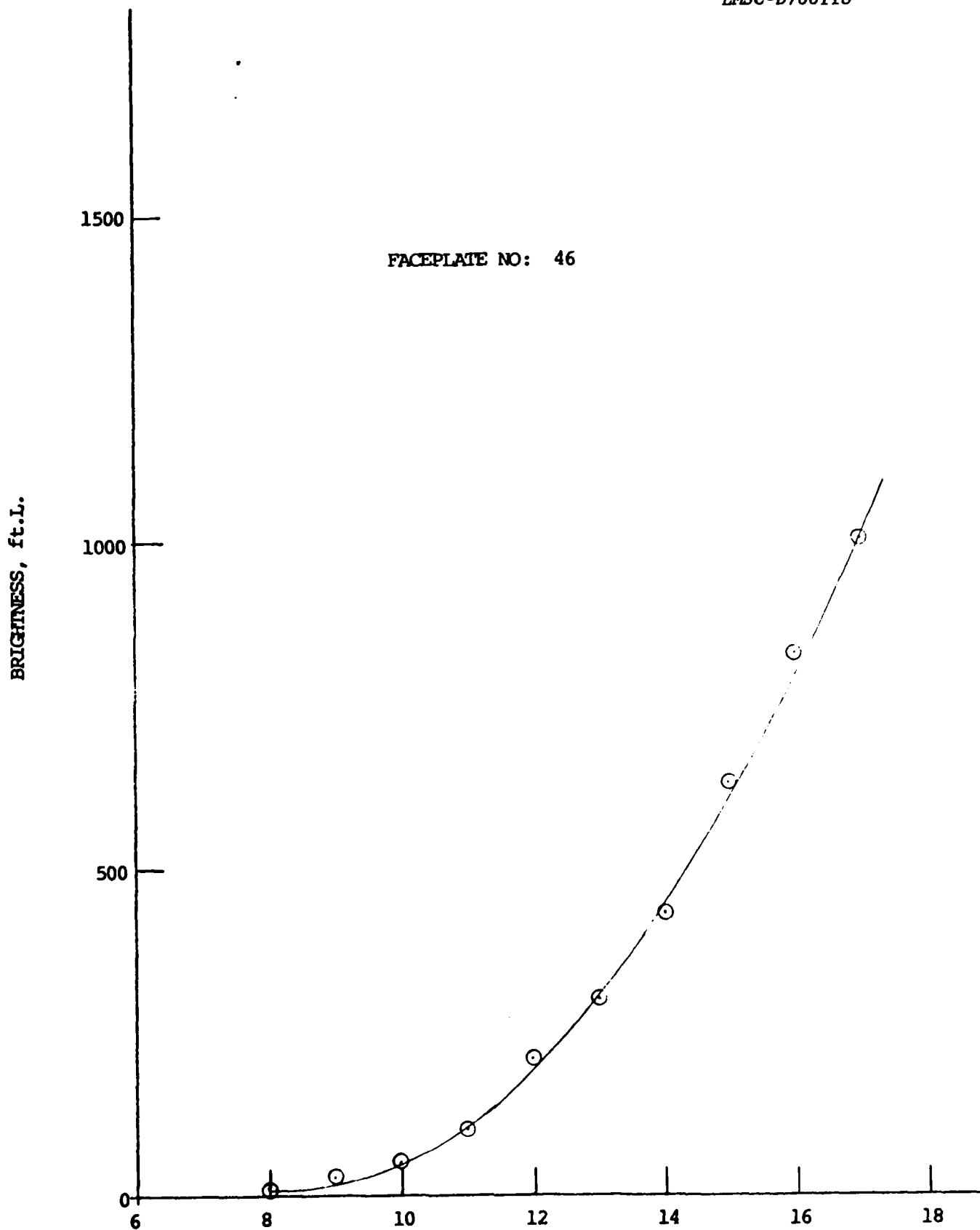


Fig. 11 ELECTRON ENERGY, Kev.

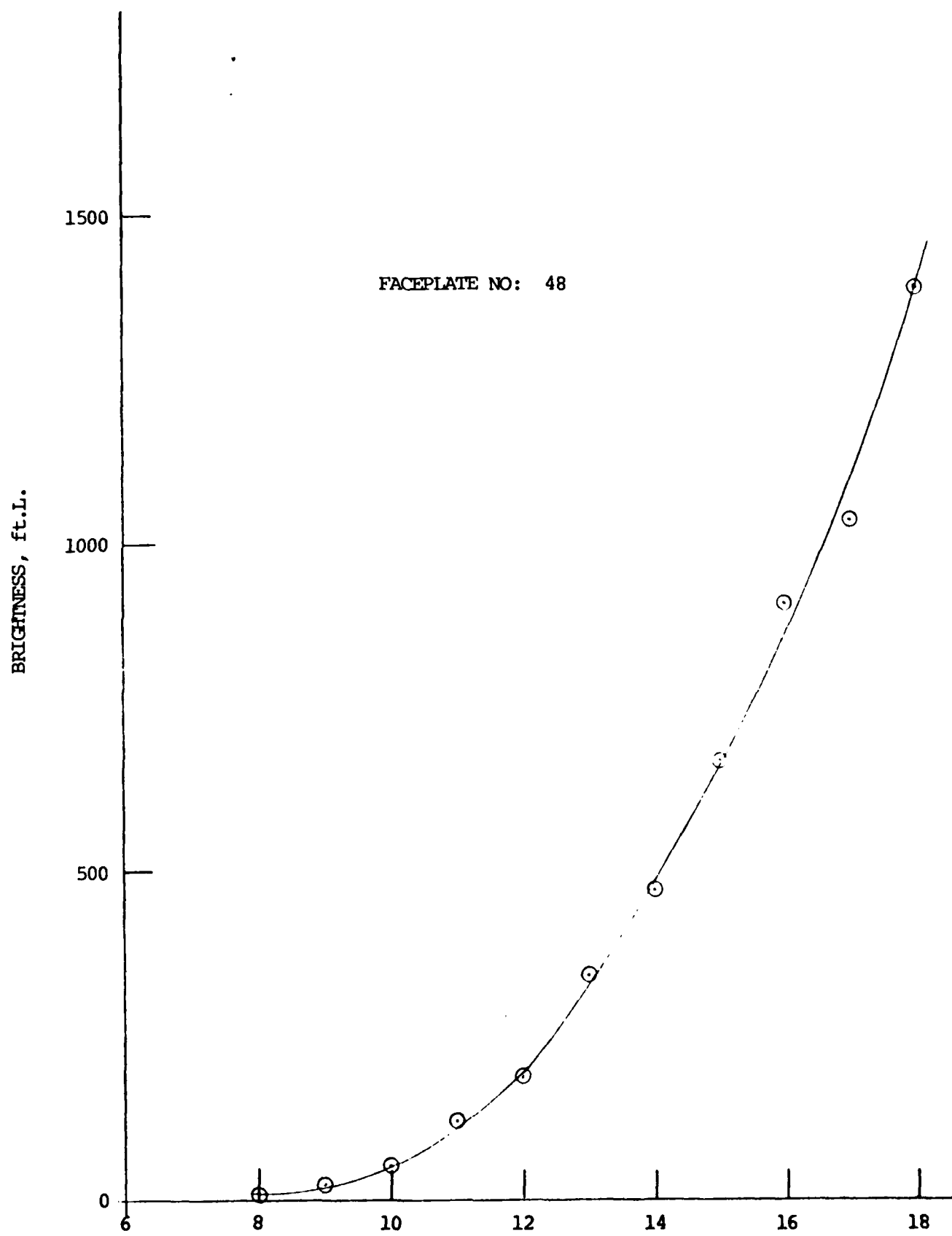


Fig. 12 ELECTRON ENERGY, Kev.

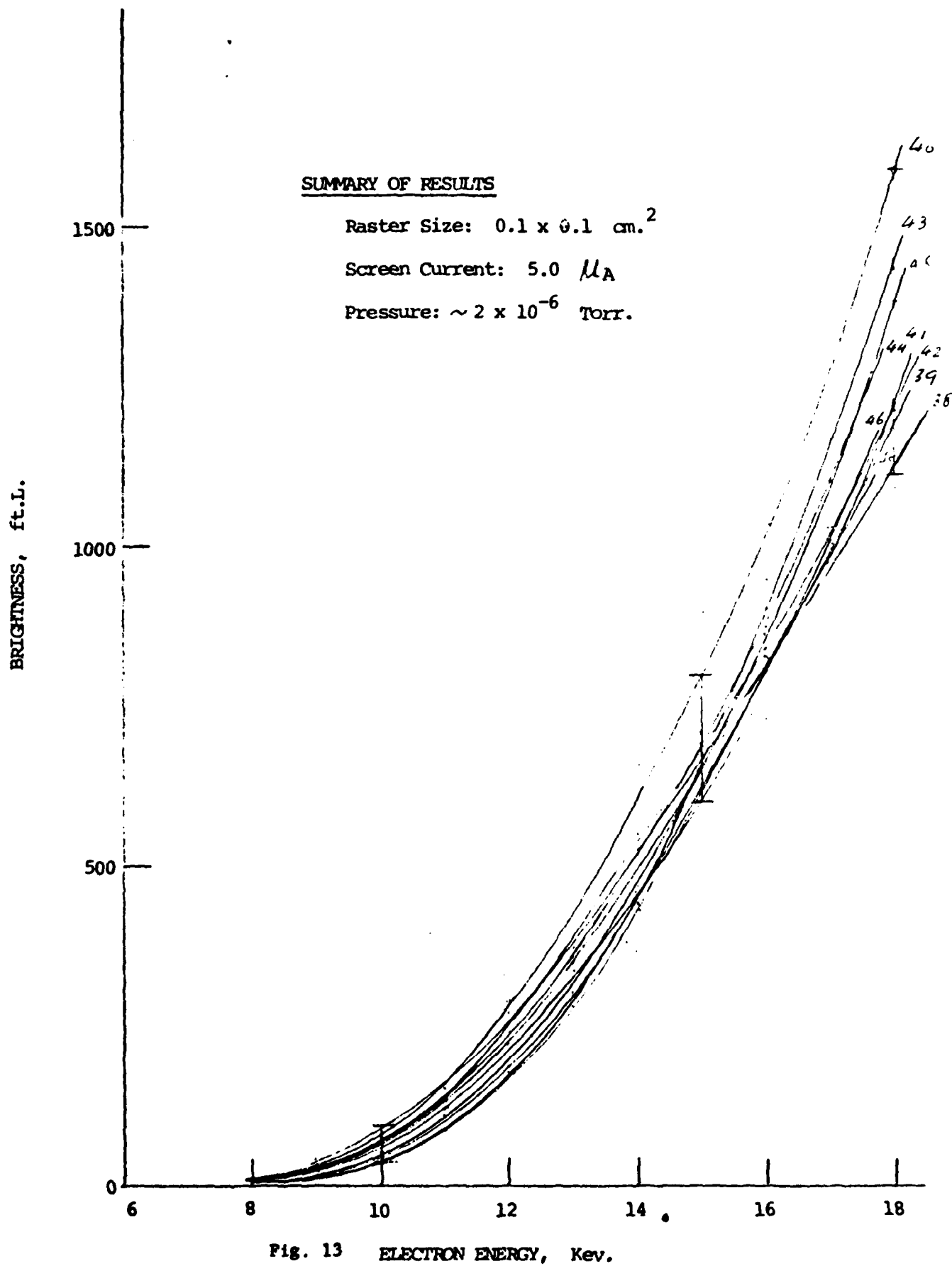


Fig. 13

4.5 Residual Sulfur Study

Arrangements were made with the Chemistry Group at the LMSC Palo Alto Laboratory for a mass spectrometer study on a typical faceplate to determine whether there is an elemental sulfur residue present following the $H_2 + SO_2$ treatment. The Varian Gas Chromatograph is capable to detecting a fraction of a monolayer.

The Chemistry group reported that 5×10^{-7} grams of elemental sulfur was found on the faceplate submitted for analysis. The sample faceplate was prepared in the standard manner, and the sulfur is a residue from the $H_2 + SO_2$ treatment. Assuming uniform distribution on both sides of the faceplate, the sulfur found corresponds to one-eighth of a monolayer. Considering that faceplates are subjected to a high vacuum during pumpdown and some warming during presputtering prior to depositing the vanadium NR films, it seems questionable whether any elemental sulfur is present on completed faceplates; this raises doubt that residual elemental sulfur is the cause of the cathode poisoning reported by the Watkins-Johnson Co.

The evaporation rate of elemental sulfur as a function of temperature can be calculated by means of the effusion equation from the kinetic gas theory (Refs. 2, 3):

$$G_N \text{ in molecules/cm}^2 \cdot \text{sec} = \frac{NP}{\sqrt{2\pi MRT}} = 3.513 \times 10^{22} \frac{P_{\text{mm}}}{\sqrt{MT}}$$

where

T = temperature in $^{\circ}\text{K}$

m = molecular weight - 32.064 g/mole for sulfur

P_{mm} = vapor pressure at T, in. Torr or mm Hg

R = the gas constant = $6.2361 \times 10^4 \text{ cm}^3 \cdot \text{Torr} \cdot ^{\circ}\text{K}^{-1} \text{ mole}^{-1}$

N = Avogadro's number = 6.02×10^{23} molecules/mole

The number of atoms in a 1 cm^3 volume can be calculated from the density ρ as

$$N(\text{cm}^3) = \frac{\rho N}{M} = 3.89 \times 10^{22} \text{ for sulfur.}$$

Also, the number of atoms per cm^2 of a monolayer is

$$N(\text{cm}^2) = \left(\frac{\rho N}{M}\right)^{2/3} = 1.1476 \times 10^{15}$$

It is known, however, that sulfur vapor consists primarily of S_6 and S_8 molecules at the temperatures shown in Table 3, so that the value of M in the effusion equation should be six to eight times the atomic weight of sulfur. For simplicity we shall take $M = 8 \times 32.064 = 256.512$ for calculation.

Table 3 shows the expected evaporation rate at various temperatures and corresponding sulfur vapor pressures.

Table 3			
$T, ^\circ\text{C}$	P_{mm}^*	S_8 Molecules/cm ² sec	Monolayer/sec
50	0.0002	2.44×10^{16}	1.70×10^2
100	0.010	1.14×10^{18}	7.95×10^3
200	2.1	2.12×10^{20}	1.48×10^6
300	48	4.40×10^{21}	3.07×10^7
400	375	3.18×10^{22}	2.22×10^8
444.6	760	6.22×10^{22}	4.34×10^8

* Ref. 4

The last column of Table I shows the equivalent number of monolayers of sulfur atoms per sec, calculated as $8G_n/N_L$. At a temperature of only 200°C , a monolayer can be expected to evaporate in less than 1 microsec.

4.6 Literature Review

A literature review of electron penetration in solids has been initiated. Although the empirical Feldman equation appears to give satisfactory range prediction for the $Al, V(NR)$ and La_2O_3S films, the resulting curves resemble truncated peaks, rather than the smooth curves of cathodoluminescent brightness vs. electron energy that have been observed. The brightness is a function of absorbed energy rather than simple electron penetration. A relationship between initial electron energy, beam density, and film thickness would be useful.

4.7 Delivery of Faceplates

Due to a combination of unavoidable factors, including a request by ERADCOM for the sulfur residue study, it became apparent in early January that the delivery of the first lot of eight faceplates to ERADCOM scheduled for January 19 could not be met. The LMSC Contract Administrator's Office notified the U.S. Army Communications and Electronics Material Readiness Command, Procurement Directorate, Fort Monmouth, New Jersey, by letter on 9 January of the contemplated delay and requested concurrence in an extension to 8 February 1980.

As only the reflectance measurements remain to be made, no problem is expected in meeting the 8 February date.

5.0

CONCLUSIONS

Annealing of aluminosilicate glass prior to film deposition did not eliminate distortion occurring during subsequent high temperature treatment. Observed distortion was, however, less severe.

Results of the cathodoluminescence are comparable to those previously reported for faceplates fabrication on 1720 glass. The CL measuring system has been found to have several deficiencies which must be corrected before valid conclusions can be drawn.

6.0

PROGRAM FOR NEXT INTERIM PERIOD

The reflectivity measurements on the first lot of 8 faceplates will be completed and the faceplates shipped to ERADCOM.

The europium concentration study will be completed.

Fabrication of the second and third lots will be made.

Optimization of the sapphire faceplate process will be initiated.

Consideration will be given to improving the cathodoluminescence measuring system to permit measurements at higher screen currents.

An effort will be made to improve the reflectivity measuring method, with particular attention to attaining more meaningful diffuse reflectivity measurement.

7.0

REFERENCES

1. High Contrast CRT, Research and Development Technical Report ECOM-77-2639-1, Jan. 1978
2. E. H. Kennard, Kinetic Theory of Gases, McGraw-Hill, N.Y., 1938, p. 63
3. J. Dushman, Scientific Foundations of Vacuum Technique, Wiley, N.Y., 1949, p. 17
4. R. C. Weast, Handbook of Chemistry and Physics, The Chemical Rubber Co., 52nd Ed., 1971, p. D-176

8.0

APPENDIX

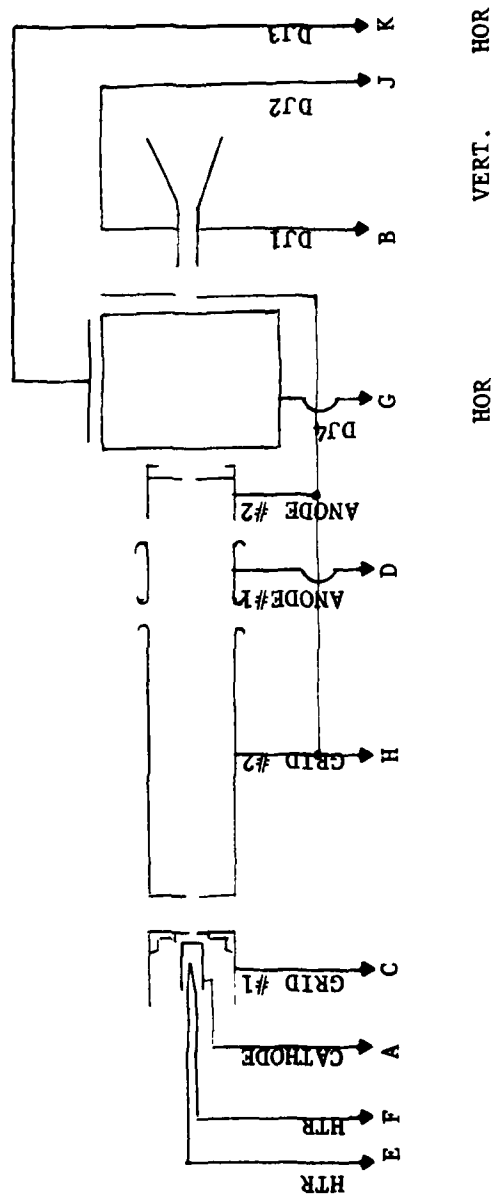
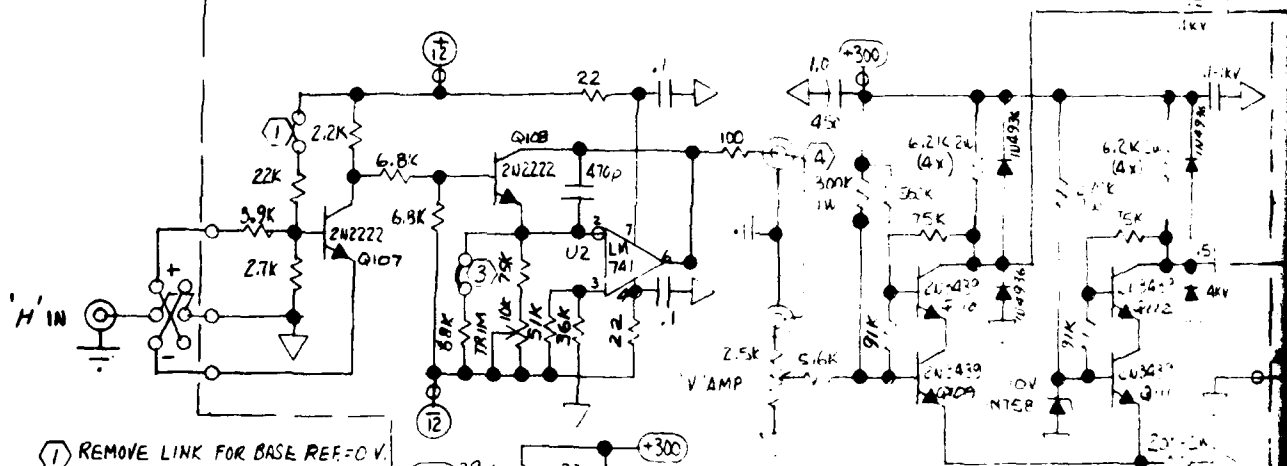

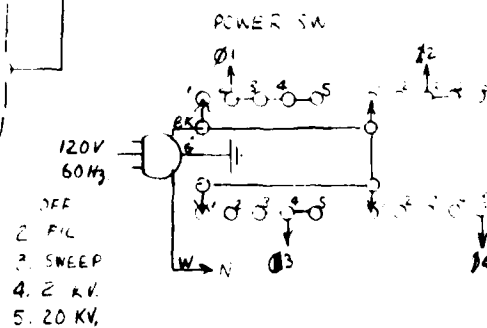
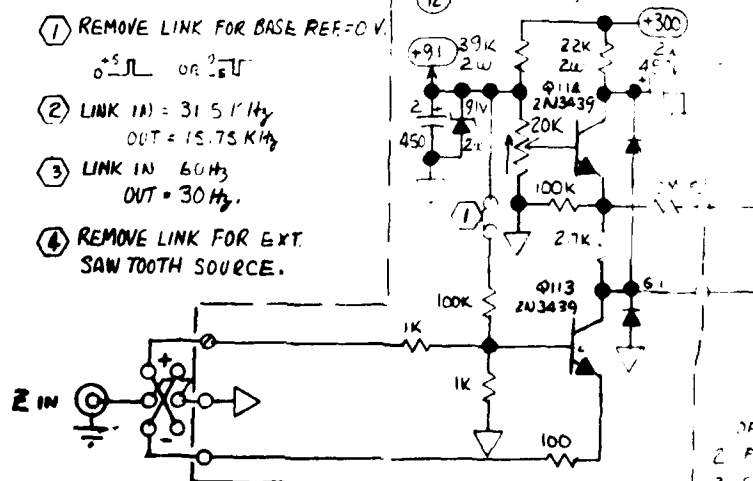


Fig. A-1 5UP1 GUN

[illegible]

- 1 REMOVE LINK FOR BASE REF = 0 V.

- 2 LINK IN = 31.5 KHz
OUT = 15.75 KHz
- 3 LINK IN = 60 Hz
OUT = 30 Hz.
- 4 REMOVE LINK FOR EXT.
SAW TOOTH SOURCE.



TF
41



THIS PAGE IS BEST QUALITY PRACTICABLE



Fig. A-3 Distortion Occurring in $H_2 + SO_2$ Treatment

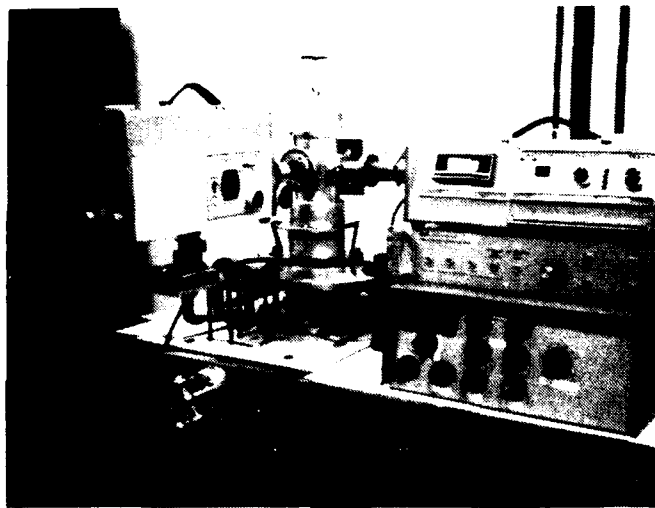


Fig. A-4 Demountable Cathodoluminescence System

DISTRIBUTION:

101 Defense Technical Information Center Attn: DTIC-TCA Cameron Station (Bldg 5) 012 Alexandria, Va. 22314	602 Crd. Night Vision & Electro-Optics ERADCOM Attn: DELMV-D 001 Fort Belvoir, Va. 22060
203 GIDEP Engineering & Support Dept. TE Section P.O. Box 398 001 NORCO, Ca. 91760	603 Cdr. Atmospheric Sciences Lab ERADCOM Attn: DELAS-SY-S 001 White Sands Missile Range, N.M. 88002
205 Director Naval Research Laboratory Attn: Code 2627 001 Washington, D.C. 20375	607 Cdr, Harry Diamond Labs Attn: DELHD-CO, TD (In Turn) 2800 Powder Mill Road 001 Adelphi, Md. 20783
301 Rome Air Development Center Attn: Documents Library (TILD) 001 Griffiss AFB, N.Y. 13441	609 Cdr. ERADCOM Attn: DRDEL-CG, CD, CS (In Turn) 2800 Powder Mill Road 001 Adelphi, Md. 20783
437 Deputy for Science & Technology Office, Ass't Sec. Army (R&D) 001 Washington, D.C. 20310	612 Cdr, ERADCOM Attn: DRDEL-CT 2800 Powder Mill Road 001 Adelphi, Md. 20783
433 HQ A (DAMA-ARZ-D/Dr. F. D. Verderame) 001 Washington, D.C. 20310	680 Commander U.S. Army Electr R&D Command 000 Fort Monmouth, N.J. 07703 1 DELEW-D 1 DELET-DD 1 DELSD-L (Tech Library) 2 DELSD-L-S (STINFO) 7 Originating Office
482 Director U.S. Army Mat'l Systems Analy. Actv Attn: DRXSY-T 001 Aberdeen Proving Ground, Md. 21005	681 Commander U.S. Army Communicatns R&D Command Attn: USMC-LNO 001 Fort Monmouth, N.J. 07703
563 Commander, DARCOM Attn: DRCDE 5001 Eisenhower Ave. 001 Alexandria, Va. 22333	705 Advisory Group on Electron Devices 201 Varick Street, 9th Floor 002 New York, New York 10014
564 Cdr. U.S. Army Signals Wrfre Lab Attn: DELSW-OS Vint Hill Farms Station 001 Warrenton, Va. 22185	
579 Cdr. PM Concept Analysis Ctrs Attn: DRCPM-CAC Arlington Hall Station 001 Arlington, Va. 22212	

103	Code R123, Tech Library DCA Defense Comm Engrg Ctr 1800 Hien...	703	NASA Scientific & Tech Info Facility Baltimore/Washington Intl Airport P.O. Box 8757
001	Reston Va 22090	001	Md. 21240
104	Defense Communications Agency Technical Library Center Code 205 (P. A. Tolovi)		Xerox Corporation Attn: Dr. Benjamin Kazan Palo Alto Research Center 3333 Coyote Hill Road
001	Washington, D.C. 20305	001	Palo Alto, Ca. 94304
206	Commander Naval Electronics Laboratory Center Attn: Library		Thomas Electronics, Inc. Attn: Mr. Peter Seats 100 Riverview Drive
001	San Diego, Ca. 92152	001	Wayne, N.J. 07470
406	Commandant U.S. Army Aviation Center Attn: ATZQ-D-MA		Watkins-Johnson Co. Attn: Mr. Norman Lehrer 442 Mount Herman Road
001	Fort Rucker, Al. 36362	001	Scotts Valley, Ca. 95066
475	Cdr. Harry Diamond Laboratories Attn: Library 2800 Powder Mill Road		
001	Adelphi, Md. 20783		
507	Cdr. AVRADCOM Attn: DRSAB-E P.O. Box 209		
001	St. Louis, Mo. 63166		
604	Chief Office of Missile Electronic Warfare Electronic Warfare Lab, ERADCOM		
001	White Sands Missile Range, N.M. 88002		
701	MIT Lincoln Laboratory Attn: Library (RM A-082) P.O. Box 73		
002	Lexington, Ma. 02173		